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Metal Progress

September, 1942

Vol. 42, No. 3

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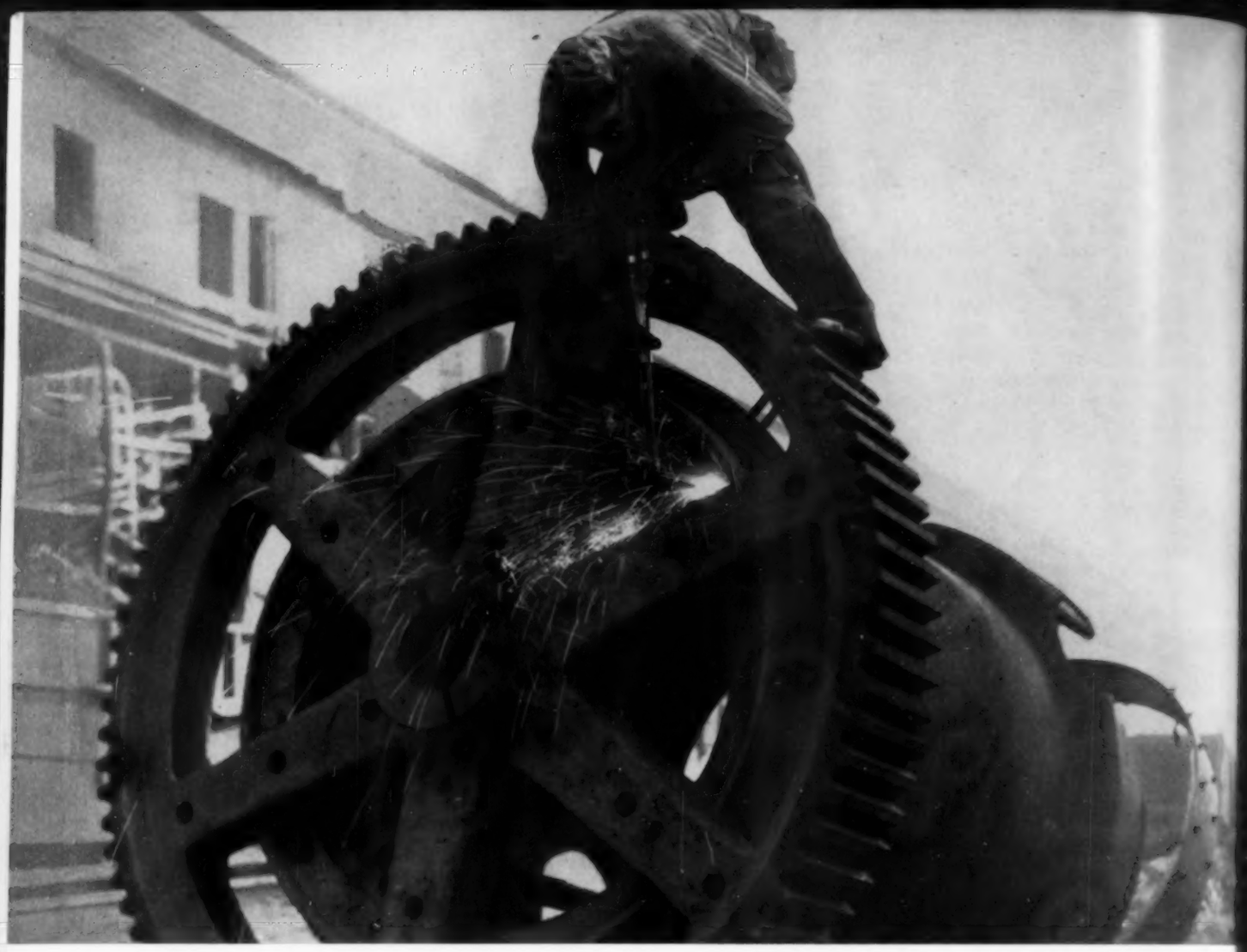

"Gertie" was cut up and fed to the Inland furnaces the day she arrived at the mills.

"Old Gertie" Goes to War

Inland Mine Hoist Makes Scrap for Hungry Furnaces

To help meet the critical need for scrap, an auxiliary mine hoist once affectionately known as "Gertie," was taken out of retirement at one of the Inland ore mines and shipped to the company's mills at Indiana Harbor. The need for scrap is so urgent that "Gertie" was cut up and fed to the hungry Inland furnaces the day she arrived at the mill. She was rolled into steel plates and soon will be part of a Liberty ship carrying vital war supplies to the fighting fronts.

"Gertie" is typical of many pieces of equipment in factories, mines, etc. throughout the country. Replaced by a modern electric hoist several years ago, this old mine hoist was stored because it "might come in handy some day." Holding old machinery, stacks, tanks, tools, jigs, dies, even partly finished parts, for possible future use is a commendable practice in ordinary times. But this is war—*total war*—and everything made of steel, that is not being used to produce for war, ought to be scrapped and started on its way to the steel mills at once.

Many steel mill furnaces are down, while millions of tons of needed scrap remain unreclaimed. The scrap situation is critical now and it will become more critical as winter approaches, unless management of American industry gives authority to scrap old equipment and materials.

If you can't use it *now*—scrap it.

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Engineering the Treatment of 155-mm. Shell

By R. F. Wilson
Metallurgist
Oliver Farm Equipment Co.
Plant No. 2, South Bend, Ind.

MANUFACTURE of 155-mm. shell, a simple tapered projectile, may be considered an easy task when comparing it with gun breeches or bomb sights. Viewing the simplicity of design, the small number of parts, and the relatively few operations necessary, one may foresee little difficulty in producing this item of ammunition. However, communications from several plants where shells are being made point to many problems along the line. We have had, and doubtless will have, problems from time to time which will be facsimiles of those encountered elsewhere. It is the purpose of this report, therefore, to give the facts as they were found and to chronicle the procedures used to work out one of these many problems, with the earnest desire that these words may be of some value to others in the shell manufacturing "industry".

Preliminary Testing

Before proceeding with production, it is necessary to carry out some heat treatment on a laboratory scale. These tests were made on sections of various shells comprising the different heats on hand at that time. A small electric furnace was used for hardening and the coupons were quenched in a small tank of 10-gal. capacity. Drawing was done in a Lindberg air draw, electric furnace of tool room size, 18×24×30 in. Coupons were treated in groups of four to give a higher degree of validity to the tests. All coupons were Brinell tested before and after drawing. Results of these tests are in Table I. The first set of tests on T-A-181-A to D was to locate the approximate treatment, and coupons of a forging coded T-A-181 were used. For easy machining, the Brinell hardness of the treated shell should fall below 228, and 196, the lower limit, was determined by the physical requirements.

Following these pilot tests, groups of coupons from various heats of steel on hand, conforming to the War Department's shell steel specification, were hardened and drawn. Results are shown in the last nine lines of Table I, page 360.

The purpose of testing in this manner was to determine the temperatures which would give the desired hardness. The hardening temperature of 1475° F. was necessarily the lowest possible, as will be noted from later data showing the critical points on this steel. Therefore, the temperature of the draw was the next important variable. It must be kept in mind that here we were seriously limited by time, since the time allowed in the draw furnace was a little less than 90 min. At least half of this is used in bringing the temperature of the shell up to approximately 1200° F.

At this point in the preliminary study, a coupon was heat treated and turned down to a standard test bar in order to get the physical properties. It was oil quenched from 1475° F., drawn 45 min. at 1200°. Its Brinell hardness

Table I — Preliminary Hardening Tests on Shell Steel

Code	Heat, °F.	Quench	Hardness	Draw, °F.	Time, Min.	Hardness
T-A-181-A	1600	Oil	321	1250	30	228
T-A-181-B	1600	Oil	302	1250	60	212
T-A-181-C	1600	Oil	302	1300	30	217
T-A-181-D	1600	Oil	311	1300	60	217
Group 1	1525	Oil	293	1075	30	255
Group 2	1525	Oil	293	1100	45	241
Group 3	1525	Oil	293	1150	30	248
Group 4	1500	Oil	286	1100	40	235
Group 5	1500	Oil	286	1150	40	231
Group 6	1500	Oil	286	1175	40	228
Group 7	1475	Oil	262	1100	40	228
Group 8	1475	Oil	262	1150	40	217
Group 9	1475	Oil	262	1175	40	217

	S.A.E. 1050	S.A.E. 1055	S.A.E. 1060
Ac_1	1335	1340	1335
Ac_3	1400	1400	1410
Ar_3	1330	1330	1370
Ar_1	1270	1275	1285

Two runs were made, one from one steel coded T-A-183 and one T-A-200 whose chemical analyses follow:

	T-A-183	T-A-200
Carbon	0.55	0.50
Manganese	0.94	0.83
Silicon	0.22	0.21
Phosphorus	0.025	0.028
Sulphur	0.034	0.032

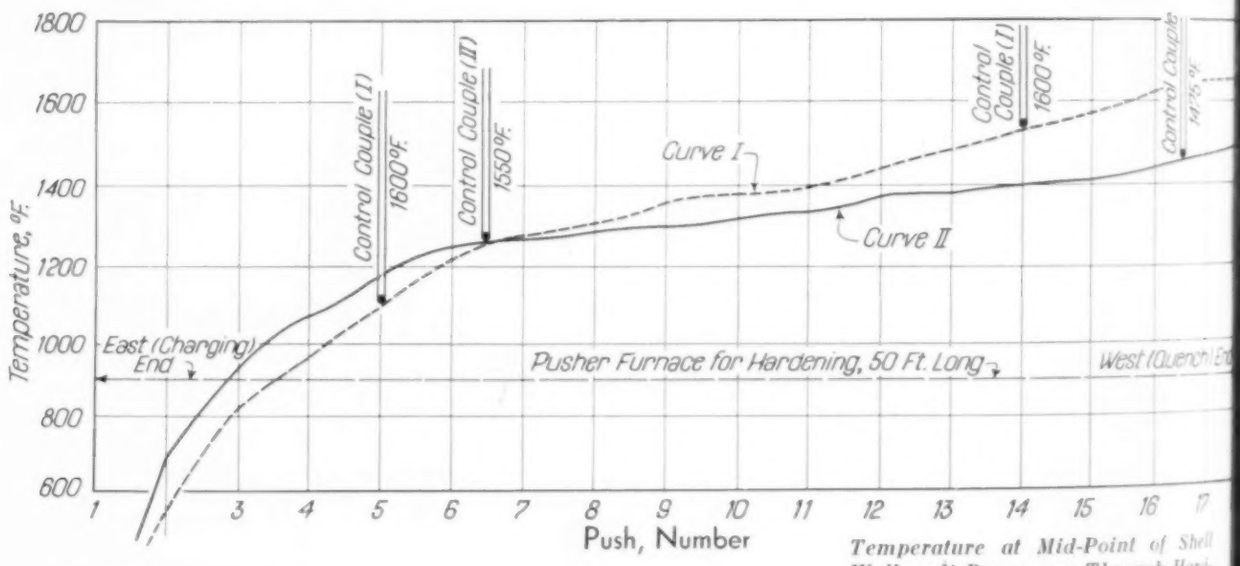
was 196, and the tensile fracture was rated "silky, ¾ cup". Tensile figures were:

Yield strength	71,500 psi.
Ultimate strength	106,000 psi.
Elongation	31.2%
Reduction of area	60.3%

A similar test piece was made, using a longer draw (60 min.) which brought the Brinell down to 192. This tensile coupon gave a yield strength of 66,500 psi., but it was decided that this value was a little too close to the required figure of 65,000 for safety.

These two heats were chosen for their wide difference in "Index Number" (3 C + Mn); for T-A-183 it was 2.59 and for T-A-200 2.33. Sizes for ideal hardenability, as computed by Grossmann's methods (see Metal Progress data sheet for July), were 1.26 in. and 1.11 in. rounds, respectively.

Not having a precision dilatometer available the critical temperatures were determined directly by using a Leeds & Northrup electric "Vapocarb" carburizing furnace, controlled by differential pyrometer and two iron-constantan thermocouples. One of the couples records the temperature of the work, and the other is located near the furnace wall. The system is so arranged that the latter couple sends an impulse which causes the pyrometer to record



Temperature at Mid-Point of Shell Wall as It Progresses Through Hardening Furnace. Test shell was outermost in an 8-row push and exceeds control temperature at discharge because of direct action of burners firing above hearth.

Determination of Critical Points

Considering the fact that W.D. SS-3 is not strictly an S.A.E. steel, it was decided that it might be of value to determine the critical transformation points. Values listed for the analogous steels, S.A.E. 1050 to 1060, on page 435 of the Metals Handbook are:

the difference between the work temperature and the furnace temperature. The power input was set at 5 kw. which equals approximately one-third the total power available; at this setting the rate of temperature increase was 100° F. per hr.; it was expected that this rate would yield a curve on which the critical could be easily read. Observations follow:

	Ac_1	Ac_{3-2}	Ar_{3-2}	Ar_1
Heat T-A-183	1345	1470	1485	1235
Heat T-A-200	1335	1455	1487	1237

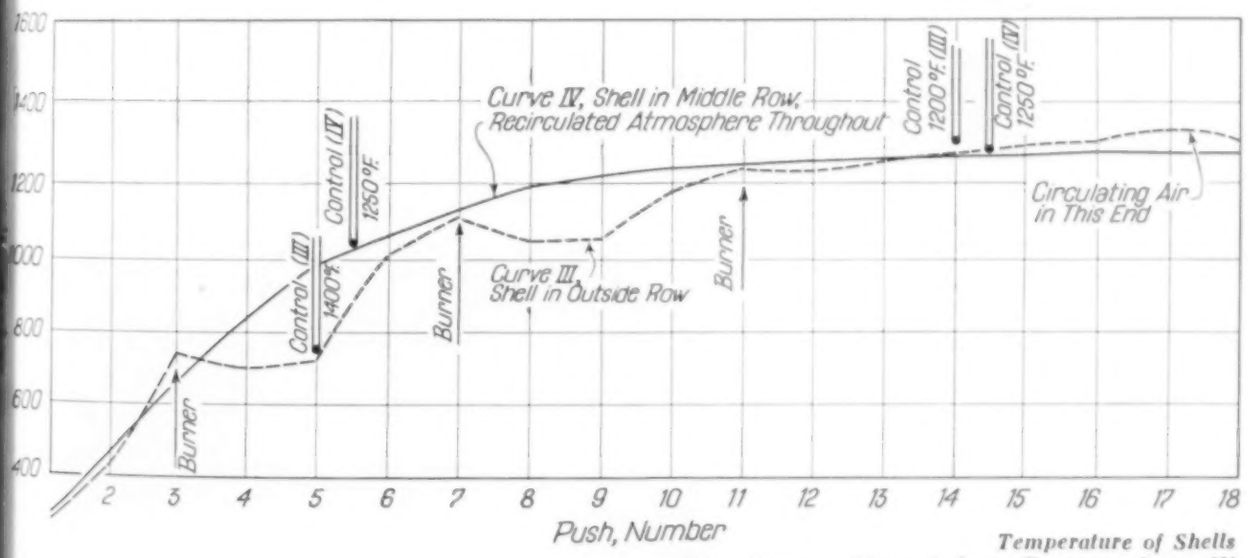
Hardening in Production

After considering these preliminary data, the capacity and design of air furnaces, and the requirements of the work as to physicals and machinability, it was decided that a 1500° F. quench and a 1300 draw would be about right, that is, quench from 25 to 50° above Ac_3 and draw from 40 to 50° below Ac_1. When the furnaces were operating so the *work* followed that schedule we achieved the required figures of 65,000 psi. yield strength, 15% elongation and 30% reduction of area, and at the same time had a well refined steel which yields a good ¾ cup, and silky fracture. Actual metallographic studies have not appeared to be necessary.

It is one thing to heat a handful of coupons in a laboratory furnace to a definite temperature, but an entirely different task to quench a half-ton of hot steel every 5 min. with equal uniformity and certainty. For this production a direct gas-fired, pusher type of furnace accommodating 144 shells was used. Each push forces one row of eight into the furnace, causing eight to drop into the quench tank at the other end. Temperature is controlled by two Leeds & Northrup Micromax recording pyrometers having a range of 200 to 2000° F., and operated by chromel-alumel thermocouples. The couples were originally placed midway in each zone (charge or east, and discharge or west) about 12 ft. from each end of a 50-ft. over-all length. Protruding through the center of the roof, they extended downward to within about a foot of the shell proper. The timing device was set between 4 and 5 min. to give a definite production.

With the furnace controls set at 1600° F. for both zones and the timer set at 4.6 minutes, a test was made on shell temperatures. We drilled a short hole in the mid-wall of a shell at its base, and cemented in the junction of a thermocouple with wires about 65 ft. long, so it could be dragged through the furnace in the regular production cycle and actual metal temperatures recorded at any time.

Temperatures were read on a portable potentiometer, and the readings recorded for each push. As may be seen from Curve I in the diagram on page 360, the temperature of the work (that is, the shell) exceeds the control temperature by 55°. This appears to be an error until it is considered that this furnace is both under-fired and over-fired; the latter causes the shell to exceed the furnace in temperature. Brinell hardness as quenched at this tempera-



Temperature of Shells as They Progress Through Draw Furnace. Curve III shows effect of side wall burners; resulting hardness varied from 186 to 217 Brinell. Curve IV gives ideal curve from furnace heated by circulating atmosphere

ture (1655° F.) was 321 to 341. (3C + Mn index of this steel = 2.57.) This condition, where the work and furnace temperatures are so far apart, is not favorable for controlled heat treatment.

To correct this variation between work and furnace, the thermocouples were replaced by longer ones, bringing the couple to within 2 to 3 in. of the shell, and both couples were moved 5 ft. toward the discharge end of the furnace. This brought the couple at the charging end back from the door approximately 16 ft. and the couple at the discharge end to within 5 ft. of the point where the shell leaves the furnace for the quench tank.

Curve II illustrates a test made as before, with thermocouples in new positions and with the furnace controls set at 1550° F. on the charging end (to accommodate for heat losses due to the opening and closing of the furnace door) and 1475° F. at the discharge end. The timer was set at 5.2 min. In this case the shell temperature immediately before the plunge (1500° F.) exceeded the furnace temperature by 25° F. This is a favorable condition, owing to the desirability of quenching on a rising temperature. Brinell hardness as quenched was 286 to 293. Curve II also shows considerable improvement over the previous one in the rate of temperature increase.

Quench Tank has a capacity of 7500 gal. The cavity of the shell is quenched by oil forced through a set of eight nozzles; this system also keeps the oil in the tank circulating vigorously. The temperature is maintained at 120° F. by pump and manually controlled valves, which circulate the oil through a water cooling jacket.

Draw Furnace

The shells are drawn back in a recirculating air draw furnace. This furnace is also gas-fired. The accommodation is also for 144 shells in rows of eight; here the shells lie on a conveyor, which advances one shell-length for each push at the hardening furnace. The same time elapses between forward movement here as does between pushes, from 4 to 5 min. according to the setting of the control. Originally there were provided two blower units, one for each zone (charging or east, and discharging or west). The fan on the charging end failed to stand up under the load of carrying this end of the furnace at 1400° F. (made necessary by the original quench from 1650° F., Curve I). To maintain production five burners were added, three on one side and two on the other, replacing the air-draw condition on this end with direct firing. The furnace was controlled by two Leeds and Northrup pyrometers with a range of 0° F. to 1500° F., using chromel-alumel couples, descending from the roof midway in each zone to within a foot of the work.

With the furnace heated as revised, the test shell was run through the draw furnace. By this time the quench temperature had been lowered somewhat from the conditions shown in Curve I and it was not necessary to draw at such a high temperature; in fact it was desirable to soak for some time at 1200° F.

Curve III resulted from this test. The furnace controls were set at 1400° F. on the charge end (to take care of heat losses at the door) and 1200° F. at the discharge end. As was the case in the hardening furnace, the work temperature exceeded that of the furnace; this case, however, shows a difference of 100 to 130° F., carried over from the charge end but not recorded on the control pyrometers owing to their position.

Added to this discrepancy is the variable condition caused by the burners. These burners were fired directly over the shell, and as a consequence, the temperature was exceedingly irregular, rising to peaks as the shell stopped in front of or near a burner, and falling below that

Photo courtesy Automobile Manufacturer

point when on the next advancement it halted between burners. This unstable condition resulted in a wide variation in hardness on the forgings, from 186 to 217 Brinell.

A second test was taken after the burners in the charging end had been removed in favor of the re-built blower, and the thermocouples placed in the sides over the shell, within an inch or two of the shell body. The curve plotted from this test is given in Curve IV. This is so far superior to the first that there can be little doubt as to the value of these tests and the corrections which were based on them. The couple on the charge end was replaced in its original position through the roof in order that the load on the front blower be controlled by the circulating air rather than the steel, since the cold shell would demand too much of the fan.

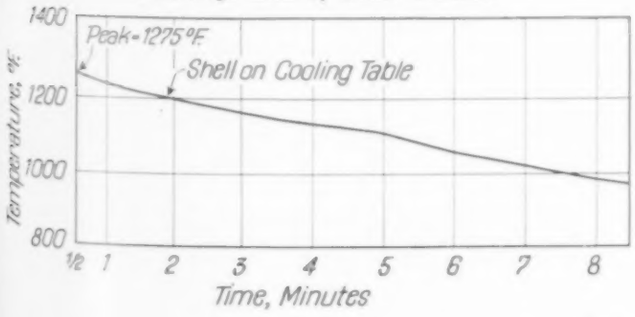
Hardness readings on the shells after these furnace improvements were installed varied within the limits of 0.1 mm. on the diameter of the Brinell depression.

Cooling After Draw

Also of importance to this heat treatment is the rate of cooling after drawing. One of the tests was delayed, and to prevent the test from being a total loss, it was decided to check the temperature during cooling. The shell was placed on the discharge table with others emerging from the furnace and allowed to travel the length of the discharge table; the time was 8 min., equal to almost two pushes.

The third figure illustrates the curve resulting from plotting the temperature against time in minutes. It may be seen from this curve that the cooling conveyor 100 ft. long, requiring 3 hr. to travel from the end of the draw furnace to the shot blast machine, would be unnecessary, and that the length could be reduced by half. An air blast brings the shell from 300° F. down to handling temperature.

Cooling Rate of Shell on Table at Discharge End of Draw Furnace



Strategic Materials

By Harvey A. Anderson
Chief, Conservation and Substitution Branch
War Production Board

FOLLOWING is a report on the relative scarcity of certain materials, as the situation appeared on August 21. [For similar reports as of March 12 and June 1, see METAL PROGRESS for April, page 552 and for June, page 850.] There is always the possibility of a quick change in the status of an item due to a sudden demand, to modifications of Government regulations, or to variations in the labor, manufacturing or transportation factors that affect the supply. For this reason the grouping in each report indicates merely the current availability of material within broadly defined categories. Materials are listed in three groups, ranked on the availability of existing supplies.

Group I consists of materials of which the supplies are inadequate for war, and for most essential uses. Civilian industry, however necessary the material may be to it, is or has been denied the use of items in Group I, and must accordingly use substitutes. All steel and zinc are now placed in this group. Scrap materials, such as iron and steel and rubber scrap, fall in this "insufficient for essential needs" category. The secondary and scrap metals are classified with the corresponding primary metal; in any given case the highest grades are the most critical and the secondary grades less critical. Items in italics are most critical.

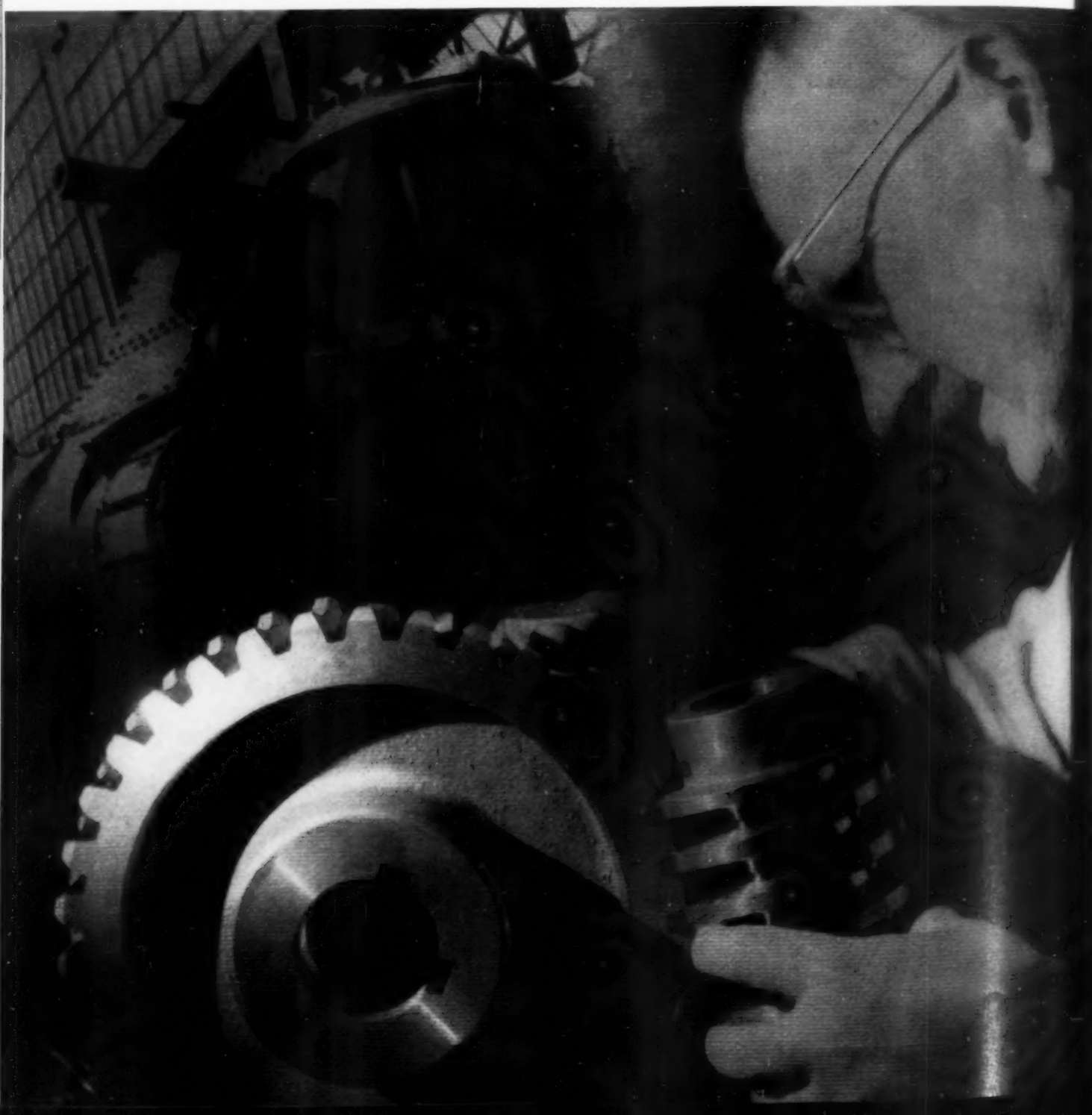
GROUP I; METALS. Alloy iron, *aluminum*, aluminum pigments, *brass, bronze*, cadmium, chromium, cobalt, *copper*, iridium, lithium, magnesium, molybdenum, *nickel and nickel alloys, steel, tantalum, tin, tungsten, tungsten carbide, vanadium*, wrought iron, and zinc.

The supply status of certain steel products in Group I is: Very critical — *alloy and shell steel, steel plates, structural steel and piling, seamless tubing ¼ in. and under, wire rope, tinplate, stainless steel.* Critical items are: Sheets and strip, wire products, black and terne plate, rails and reinforcing steel, semi-finished *(Continued on page 414)*

They Also Serve

Photographic Montage by H. G. Stokes

May Show, 1942, Cleveland Museum of A



Appraisal of NE Steels in terms of old types

By Francis B. Foley
Superintendent of Research Dept.
The Midvale Co.
Nicetown, Philadelphia

THE HARDENABILITY of steels of various compositions is a property which is now being used by engineers in addition to the usual type of physical properties chart to indicate what may be expected when the steel being studied is treated in sizes larger than the conventional 1-in. round used in the compiling of physical properties charts. GROSSMANN and his associates have shown, in various recent contributions to *Transactions*, how the data obtained in a hardenability test can be used to predict mass effects in heat treatment and how the data from a large number of hardenability tests of steels of various compositions can be used to predict the hardenability of untested hypothetical or actual compositions (see METAL PROGRESS' Data Sheet for July, page 81).

All the elements commonly encountered in the composition of the usual run of engineering structural steels contribute to their hardenability excepting sulphur. Cobalt is cited usually as the exception but it is never used as an alloy in the steels under discussion. Various combinations in various amounts of the elements produce a tremendous number of possible alloy steels, each varying in some degree from the others in this property of hardenability. The grain-growth characteristics (austenitic grain size before quenching) also enter as a variable affecting hardenability.

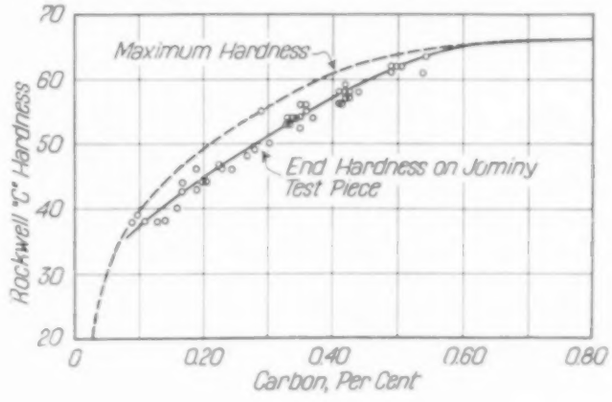
The purpose of this article is to suggest a method of evaluating the relative hardness of steels from a minimum of data.

A family of JOMINY end-quench hardenability curves is shown in the diagram on page 387 of this issue which covers a single type of alloy steel (carbon-molybdenum) of various carbon contents. They give two classes of information which are used in two derived curves.

First of all the intercept of four end-quench curves on the zero axis gives the maximum hardness obtained in the JOMINY end-quench test for each of the carbon contents tested. These points may be plotted against carbon content to obtain a curve showing the maximum hardness obtainable for any carbon content of this type of steel.

Families of similar curves have been determined for a number of different alloy steels (including numerous examples of the National Emergency series) and when the maximum hardness values for a given carbon content are plotted the points in Fig. 1 result. The solid

Fig. 1 — Maximum Hardness at Quenched End of Jominy End-Quench Bar, of Numerous S.A.E. and NE Steels, Plotted Against Respective Carbon Contents. Dotted line is relation between carbon content and maximum quenched hardness as determined by Burns et al. in the book "Hardenability of Alloy Steels"



Range of Analyses in Steels Studied

TYPE	MN	SI	NI	CR	MO
S.A.E. 4300	0.60 to 0.80	0.20 to 0.35	1.65 to 2.0	0.60 to 0.90	0.25 to 0.35
NE 8500	1.3 to 1.6	0.20 to 0.35	....	....	0.40 to 0.60
NE 8700	0.75 to 1.0	0.20 to 0.35	0.40 to 0.60	0.40 to 0.60	0.20 to 0.30
S.A.E. 4600	0.60 to 0.80	0.20 to 0.35	1.65 to 2.0	....	0.20 to 0.30
S.A.E. 4000	0.70 to 1.0	0.20 to 0.35	....	....	0.20 to 0.30

curve passing through these points gives the carbon-hardness relationship and indicates that within experimental error of 1½ points, plus or minus on the Rockwell C scale, the relationship is independent of the alloy content. As already noted these points were all obtained from charts of S.A.E. and NE steels obtained by different investigators and which have been issued by the American Iron & Steel Institute during the past several months as "Supplementary Information on Alloy Steel, Section 10." The maximum hardness indicated for a given carbon is not as great as that given as *maximum* possible hardness in curves of the same type published heretofore, and shown by the dotted curve in the same figure, because the quench in the JOMINY end-quench test on a 1-in. bar is not as drastic as is possible on a somewhat smaller piece.

The next set of data to be derived from hardenability curves such as shown on page 387 produces the curves shown in Fig. 2, 3 and 4. Curves such as these are derived by taking from the end-quench curves for steels of each carbon content the distance from the end at which a hardness of Rockwell C-50, 40 or 30 respectively was obtained. These distances are plotted against the corresponding carbon content and produce a curve representing the effect of carbon on the hardenability of this alloy.

All of the curves in Fig. 2, 3 and 4 were obtained in this way from the same source as the data used in Fig. 1. Composition ranges are given in the table above. Note that the curves for all types of alloy steels in these figures converge to a common carbon content on the horizontal axis (zero-distance or face of the quenched specimen). This point (C 0.28% for C-50, C 0.14% for C-40 and C 0.05% for C-30) is the maximum carbon content capable of attaining the hardness represented by the figures, and may be derived from Fig. 1.

With Fig. 1 established the zero-distance point is fixed for Fig. 2, 3 and 4. Now, to determine the relative hardenability of a new steel it is necessary to have a single determination, made at, say, carbon 0.30 or 0.40%, or at most two determinations at, say, carbon 0.35 and 0.45% to place the curve for the new steel with reference to the others of known hardenability.

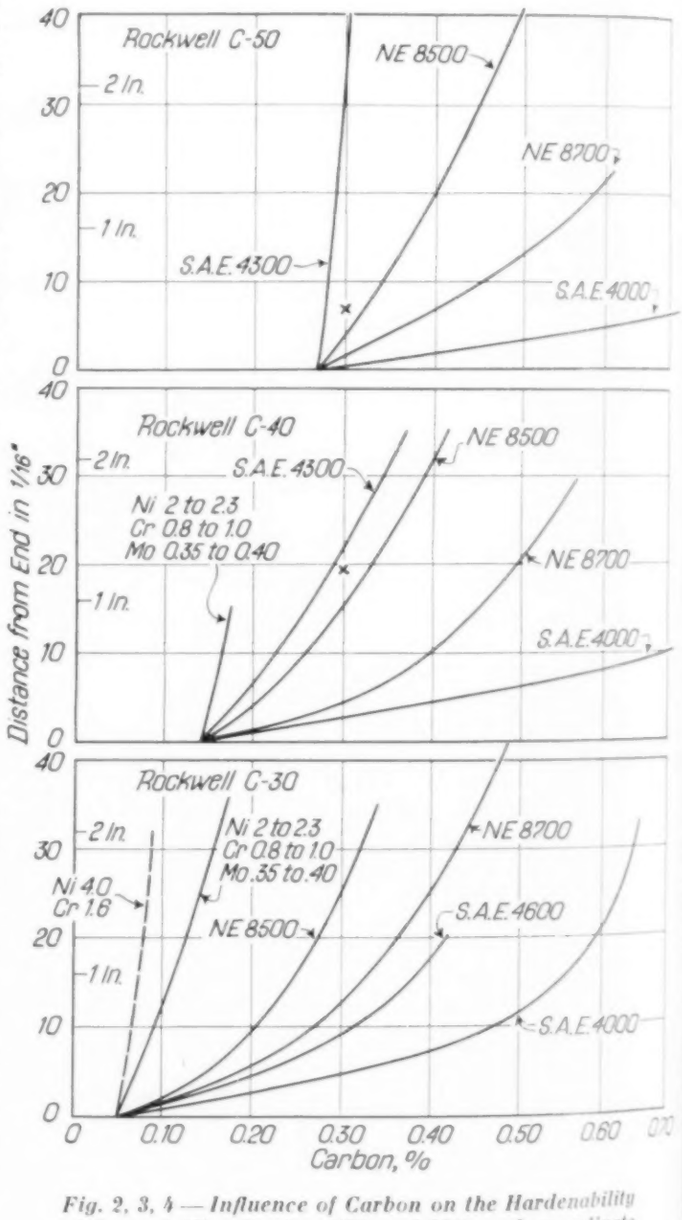


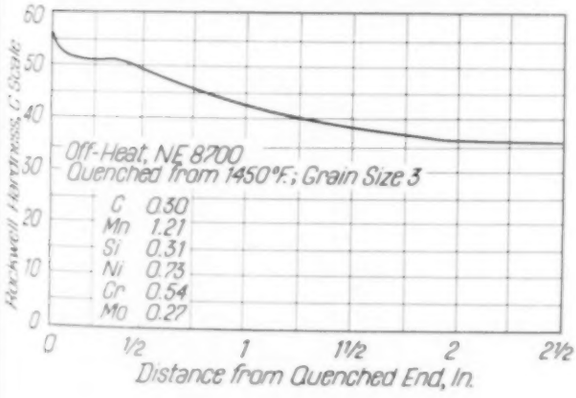
Fig. 2, 3, 4 — Influence of Carbon on the Hardenability of Several Alloy Steels. "X" on 0.30% carbon ordinate represents a plot for an off-heat of NE 8700 (high in manganese and nickel) and indicates that its response to heat treatment will approach that of S.A.E. 4300

How this method of plotting may be used is illustrated in evaluating the hardenability of a steel such as the one producing the JOMINY curve in Fig. 5. This steel differs from the 8700 series of National Emergency steels in that its manganese and nickel are both high. By deriving the distances for C-50 and C-40 from Fig. 5, and plotting them on the 0.30% carbon vertical in Fig. 2 and 3 respectively, it develops that this type of steel approaches the S.A.E. 3200 series in hardenability and has better response to hardening than NE 8500.

Curves such as these may be made up for any of the steels that have been in production in an individual plant, and whose treatment and responses are thus well known. They are then ready for use in many ways. Note, for example, how some curves in Fig. 2, 3 and 4 swing upward on their ends, denoting that the depth hardening of some types of steels increases very rapidly with increase in carbon content, whereas in others — plotting as a straight line — carbon has relatively little effect.

If one plots such a series of curves for a given type of steel, he may then match harden-

Fig. 5 — End-Quench Hardenability Curve for Off-Heat of NE 8700 Steel, High in Both Manganese and Nickel. The text indicates how its response to heat treatment can easily be appraised, in relation to the performance of familiar steels, handled for years in production



ability results from purchased stock against it to determine any marked departure, and thus check quickly on the effect of variations in carbon (and other elements for that matter) against expected performance. Then, by using temperature as a variable in the JOMINY test, a hardening temperature may be arrived at which will compensate for a departure from the hardenability characteristics established by standard procedure.

Inspection of Spot Welds in Aluminum

AMERICAN Welding Society's Aircraft Resistance Welding Standards Committee (GEORGE S. MIKHALAPOV, chairman), in cooperation with Resistance Welder Manufacturers' Association, has formulated some "Tentative Standards and Recommended Practices and Procedures for Spot Welding of Aluminum Alloys" which have been approved as an emergency standard by the National Aircraft Standards Committee. It is a document containing as much text as a complete issue of METAL PROGRESS, and discusses fully the preparation of the material and welding technique, standards of quality, methods of testing and inspection, design of welded joints, the equipment, personnel and production engineering. From this mass of material, a few hundred words will be extracted bearing on inspection.

STANDARDS OF INSPECTION should give positive assurance both to the designer and the user of aircraft that the welding present is in accordance with the prescribed standards of quality and that all welding which for some reason may not meet with these standards is either rejected or salvaged by suitable repairs.

The Inspector — Since a great deal of spot welding inspection must be visual, a high degree of skill and experience is required from a keen-eyed inspector if he is to exercise his job with efficiency and dispatch. For this reason it should be a full-time job.

The execution of routine tests imposes time-consuming duties on the inspector, irrespective of the quality of the welding produced. Nevertheless, he should have considerable time free from this routine, during which he may observe the operation of the equipment, its personnel, and the general functioning of the department, and therefore be able to advise the operator or supervisor at the first sign of incipient trouble.

An inspector's mentality should be such that he should regard himself and his job as one where the ultimate quality of the product can be best secured by his cheerful and helpful cooperation with the entire production department personnel and his capacity for constructive rather than destructive *(Continued on page 418)*

Composite Railroad Bearing Conserves Copper

By E. S. Pearce
President
Railway Service & Supply Corp.
Indianapolis, Ind.

HAVING BEEN ASSOCIATED with the service and operation of railroad journal bearings on a large number of railroads for several years, although not a manufacturer of the bearings themselves, the report by the Advisory Committee of the National Academy of Sciences to the War Production Board on "Secondary Copper for Bearings", printed in METAL PROGRESS for August, has been most interesting and informative. I was particularly impressed with Paragraph *(d)* of the report, under *Recommended Procedure*, for the reason that this is an actuality at the present time. The recommendation may be restated here:

"*(d)* That an insistent and rapid effort be made by a joint conference of competent engineers in the railroad, bearing and automotive industry, to design and study in service a bearing requiring no change in existing boxes wherein the major portion of the bronze back is replaced by a malleable iron casting or other material, more available than a 70% copper bronze."

It happens that several years ago Railway Service & Supply Corp. started a research program for the purpose of improving the performance of railroad car journal bearings — although, as stated above, we are not bearing manufacturers. We built a very complete test plant upon which we can operate a full size 5½×10-in. journal under any conditions of speed, load and temperature, and obtain data as to temperature rise and power losses. We therefore have a great amount of data on this subject accumulated over a period of ten years and have, incident to the work, developed several improved railroad bearing constructions.

For this reason we were able to submit a tested and proved design of railroad bearing, interchangeable with the present American standard but using much less non-ferrous metal, when we were called into conference with bearing manufacturers and railway maintenance engineers in January. This meeting was arranged by the Association of American Railroads at the request of the War Production Board, probably as a result of the National Academy's Recommendation *(d)*, and was asked to instigate a prompt program for the conservation of copper and the other strategic metals in railroad use.

The first thing this conference did was to change immediately some dimensions of the standard bearing. These changes were long overdue, as some details on the old bearing were known to encourage replacements. Service statistics show that eight causes of replacements, accounting for 57% of the bearings used, are primarily affected by material, dimensional and manufacturing conditions. Only 3% of the bearings were removed because they are "worn out".

The Committee's work produced the so-called "modified car journal bearing", which became standard for freight cars Jan. 15. An additional modification known as the "emergency bearing" was made and adopted April 4, which further reduced the weight of the bearing; it is now about 4 lb. lighter than the old standard A.A.R. bearing. This, apparently, is the limit to which weight can be removed from the old standard bearing.

Temperature Rise (°F.) After 8-Hr. Run

Region Measured	Speed, Miles per Hr.			
	40	60	80	100
Journal				
Standard A.A.R.	132	178	204	262
Composite	118	158	192	236
Bearing				
Standard A.A.R.	122	165	198	237
Composite	110	146	180	220
Wedge				
Standard A.A.R.	107	135	163	204
Composite	80	108	134	162
Top of Box				
Standard A.A.R.	55	81	96	113
Composite	43	59	75	90

Further modifications to save more weight must depend on a radically different design. Four major conditions, however, must be met:

1. The bearing must be interchangeable with the present bearing on the spot with no collateral or auxiliary changes in other related parts of the journal box assembly.

2. No additional or involved operations in application or removal of the bearing from the journal must be required.

3. The structure to be adopted must be possible of widely distributed production by facilities now in existence, possible of production on a quantity basis, and employ as little critical materials as possible.

4. It must have an assured continuity of operation and an equal or greater factor of safety than the present bearing, which must be capable of demonstration relatively quickly.

To meet these conditions, Railway Service & Supply Corp. submitted the bearing shown in the drawing, and developed a pilot plant for its manufacture. In this bearing we incorporated several of the developments we had studied in four previous designs. We have had several years' service experience with many of the features, as they have been incorporated in bearings of which many thousands are in service. It also fits the Recommendation *(d)* so specifically that it consists of a fairly thick malleable iron adapter and a brass layer $\frac{5}{16}$ in. thick lined with $\frac{3}{16}$ in. of babbitt. The adapter has the physical shape and dimensions of the present bearing, so it assures interchangeability without modification in the box assembly; like the conventional wedge, it will be a permanent part of the journal box assembly. The mechanical and stores forces will handle an 8.37-lb. bearing in the 5½×10-in. size instead of the 25.89-lb. bearing which they now handle.

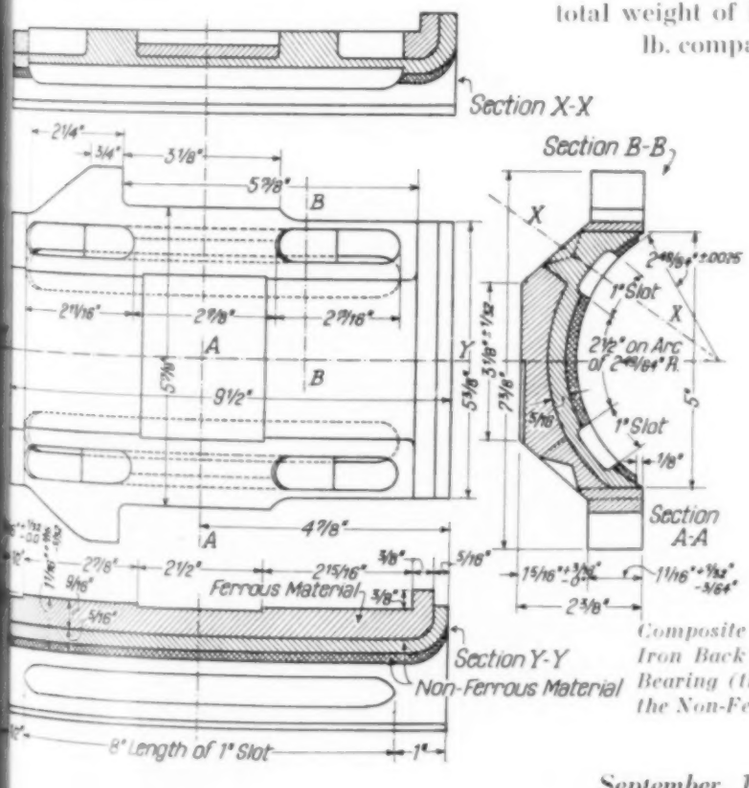
Comparison of this composite bearing with the prevailing standard illustrated in August Metal Progress, page 223, gives the following weights of strategic metals:

	Present Standard	Composite
Copper	15.78 lb.	4.33 lb.
Tin	1.25	0.35
Lead	8.39	3.69
Antimony	0.47	none
Total	25.89 lb.	8.37 lb.

The malleable iron adapter weighs 9.19 lb., so the total weight of bearing and adapter is therefore 17.56 lb. compared to the old (1941) standard bearing, which weighs 25.89 lb., all of which is strategic non-ferrous metal.

This should be an attractive prospect for conservation. When one is notified by the War Production Board that copper and its alloys may no longer be used in non-current carrying parts of electrical fuses, and the justification is given that such a change will save 1200 tons of copper annually, one wonders why more pressure is not being brought to bear on such a large source of recoverable copper as railroad bearings. My figures

(Continued on page 416)



Composite Freight Car Bearing That Utilizes Malleable Iron Back and Relatively Thin, Babbitt-Lined Bronze Bearing (the Replaceable Unit) and Saves Two-Thirds the Non-Ferrous Metals in the Present Standard Bearing

Suitability of Alternate Steels for Aircraft Parts

By A. C. Willis
2nd Lt., Army Air Forces
and Morse Hill
Materiel Center, Wright Field

NATIONAL EMERGENCY STEELS have been designed for the conservation of the strategic alloying elements, nickel, chromium, vanadium, tungsten and molybdenum. Although the actual total alloy content of these steels may be equal to or exceed that in the older "standard" steels, conservation is accomplished by a better balance between the added alloying elements and those which are present to an increasing extent in the scrap returning to the mills for remelting. Due to the large increase in alloy steel consumed in the munitions program, this return scrap is becoming richer in all of the alloying elements, and the necessity of using the emergency steels becomes more apparent.

The NE8000 (National Emergency) series of steels is a tribute to the technical skill of the American metallurgists and their accumulated knowledge of the specific effect, the correct and balanced combinations, and the intensifying action of each alloying element. These new, complex, low alloy steels have been designed to meet the requirements for performance, to conserve the strategic elements and to make available a larger tonnage of steel for the armed forces and the auxiliary civilian effort. In addition to the NE8000 series, other steels such as the carbon-molybdenum S.A.E. 4000 steels, which have been used by the automotive industry are being studied for their application to the aircraft industry. Likewise it is probable that other new steels besides the NE8000 series will be developed. All these steels will be referred to in these reports as "alternate steels".

For the aircraft industry, the *quality* of steel is more closely restricted than for many other uses, and specifications for the alternate steels suitable for aircraft use must include more than chemical composition. Specifications established by the Government and by the Aircraft Materials and Processes Coordinating Subdivision of the Society of Automotive Engineers

Table I — Tentative Alternates for Bar Steel, Aircraft Quality

Specification	Chemical Composition *(a)*					Old A.M.S. Specifications *(b)*
	C	Mn	Ni	Cr	Mo	
AN-S-9 *(4037)*	0.35 to 0.40	0.75 to 1.00			0.20 to 0.30	Alternate for aircraft bolts, ¾ in. and under, of 2330 steel
A.M.S. 6280 *(8630)*	0.27 to 0.33	0.70 to 0.90	0.40 to 0.60	0.40 to 0.60	0.15 to 0.25	6370 [4130, Cr-Mo]★
A.M.S. 6320 *(8735)*	0.33 to 0.38	0.75 to 1.00	0.40 to 0.60	0.40 to 0.60	0.20 to 0.30	6310 [4635, Ni-Mo]★; 6330 [3135, Ni-Cr]; 6380 [4138, Cr-Mo]
A.M.S. 6322 *(8739)*	0.38 to 0.43	0.75 to 1.00	0.40 to 0.60	0.40 to 0.60	0.20 to 0.30	6312 [4640, Ni-Mo]★; also 6332 [3142, Ni-Cr]; 6380 [4138, Cr-Mo]; 6448 [6150, Cr-V]; 6382 [4140, Cr-Mo]

(a) Silicon 0.20 to 0.35%; phosphorus and sulphur, each 0.040% max.

(b) A.M.S. specifications for which tentative alternate steels are suggested for investigation.

★Matter in brackets has been added by The Editor of Metal Progress, as a ready (but not exact) correlation of A.M.S. specification compositions and S.A.E. or A.I.S.I. steel analyses.

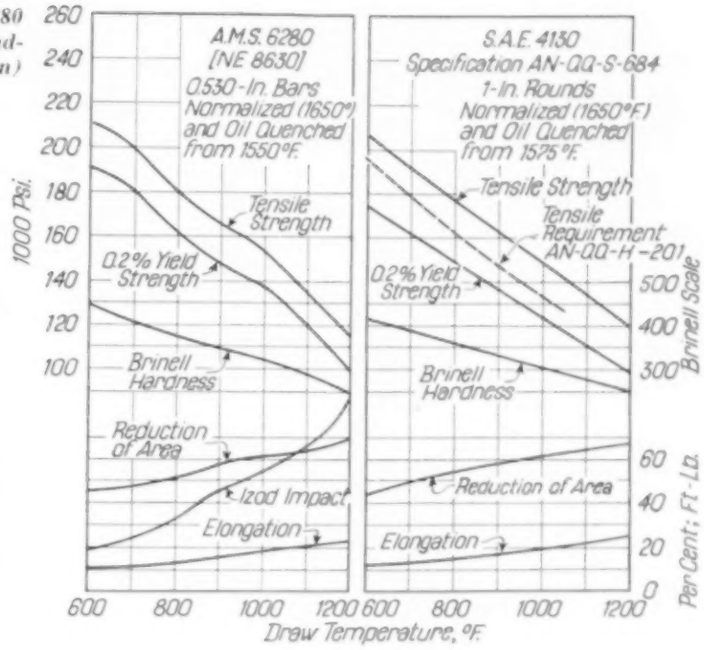


Fig. 2a and 2b — Properties of A.M.S. 6280 [NE8630], a Possible Alternate for the "Standard" Steel S.A.E. 4130 (AN Specification)

(the so-called A.M.S. or "Aeronautical Material Specifications") have been used in the past for "standard" steels, and similar *quality* specifications have been or will be prepared for the alternate steels.

Transition to these alternate steels will require that data are obtained and studied on the mechanical properties, forgeability, weldability, machinability and other factors affecting their application in the aircraft industry. The high requirements of the industry need not be lowered, and there is no implication that these steels will not fulfill the high standards previously established. [It is to be understood by contractors, of course, that the application of alternate steels in specific parts is subject to approval by the procuring agency.]

The Army Air Forces have initiated a program for gathering, analyzing, condensing and distributing the results of the investigations of these steels in order to expedite the utilization of the alternate steels in the industry. This report (Serial No. 4799, dated July 9, 1942) is the first of a series growing out of this program, and deals with steels procured in accordance with the following specifications: AN-S-9, A.M.S.6280, A.M.S.6320, and A.M.S.6322. Reports from industrial concerns having laboratory facilities and technical staffs, the results of laboratory testing at the Materiel Center, and other factual information, are combined to give a comprehensive analysis. The steel producers and fabricators are urged to cooperate with this program by submitting additional information of practical value regarding physical properties, hardenability, heat treatment practice, machinability, forgeability, and other information important to the adoption by the aircraft industry.

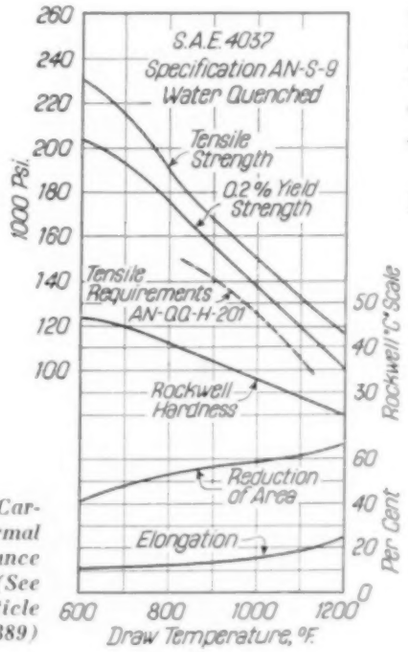


Fig. 1 — Tensile Properties of Carbon-Molybdenum Steel 4037. Normal expectancies as given in Ordnance Dept. chart issued May 5, 1942. (See also curves in Mr. McCleary's article on p. 387 and the data sheet, p. 389)

The chemical compositions given in A.M.S. specifications, as shown in the accompanying Table I, were recommended by the Technical Advisory Committee for Aeronautical Steels, organized by the Bureau of Industrial Conservation, War Production Board. The data on physical properties have been obtained from the reports of several industrial organizations† and laboratory tests at the Materiel Center. An effort has been made to bring out all of the significant facts and to present them in a form that can be readily interpreted.

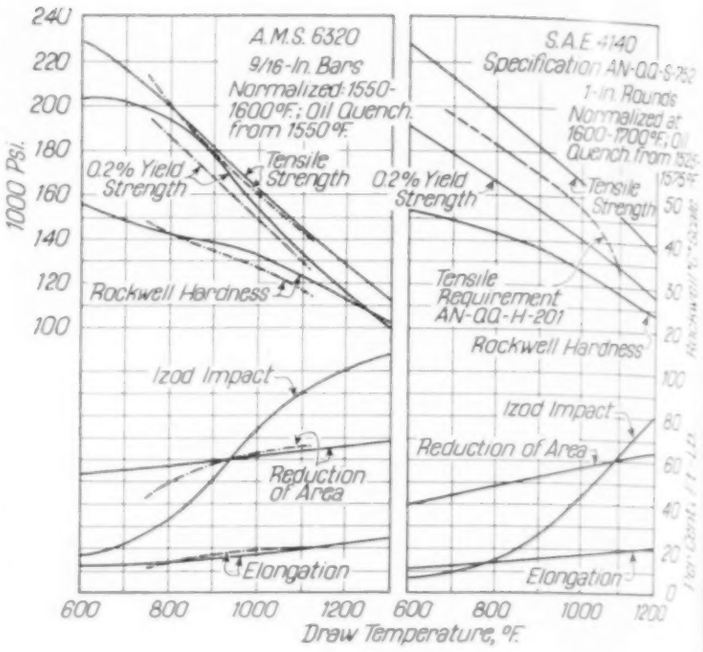
The testing conducted by the Army Air Forces at the Materiel Center followed an accepted and standardized procedure, and because it is typical of the testing by industrial and professional organizations, it will now be briefly outlined:

The Materiel Center procured one lot of A.M.S.6320 [8735] and A.M.S.

†To obtain further data, the following were abstracted:

1. American Iron and Steel Institute, "Contributions to the Metallurgy of Steel, No. 5", January, 1942.
2. Climax Molybdenum Co., "Molybdenum in Steel".
3. Curtiss-Wright Corp., Airplane Division, Report No. 42-55, March 13, 1942.
4. Packard Motor Car Co., Aircraft Engine Division, Report No. RR-48, April 29, 1942.
5. Republic Steel Corp., Report No. 5984-11 [printed in METAL PROGRESS, June 1942, page 793].

Fig. 3a (left) — A.M.S. 6320 Steel as Tested at Wright Field (Full Line) and by Packard Motor Car Co. (Dash-Dot Line). Fig. 3b (right) — A Comparable "Standard" Steel S.A.E. 4140



6322 [8739] steels as 1⅛-in. rounds from the Copperweld Steel Co. Grain size of these steels was determined by A.S.T.M. specification E19-39T, Method A. Bar specimens were slotted, then heated one hour each, and broken for grain coarsening determinations.

A sufficient stock of the two steels was then normalized at 1650° F. to provide material for hardenability, tension, impact and fatigue specimens. Jominy hardenability tests were conducted, and a bar 3 in. long from each lot was quenched in oil for traverse hardness tests of the central portions.

Standard tensile, Izod impact, and rotating-beam fatigue specimens were rough machined from both lots, 0.020 to 0.030-in. oversize, quenched in oil, and drawn at several temperatures. After finish machining, tensile tests were conducted, and Izod impact specimens were broken at both room and sub-atmospheric temperatures. Tests at sub-atmospheric temperatures were conducted in a cold room in which both the testing machinery and the specimens were at the temperature selected. Fatigue studies have been started but the results are not yet available.

Table II — Analyses of Steels Tested in Fig. 1 to 4

Fig.	Designation	C	Mn	Si	P	S	Ni	Cr	Mo	Grain Size	Data by
1	S.A.E. 4037	Normal expectancy of standard analysis.....									Ordnance Dept. Chart, May 5, 1942
2a	A.M.S. 6280 [NE 8630]	0.30	0.80	0.25	0.014	0.015	0.42	0.49	0.22	7 to 8	Republic Steel Corp.
2b	S.A.E. 4130	Normal expectancy of standard analysis.....									Climax Molybdenum Co.
3a	A.M.S. 6320 [NE 8735]	0.34	0.87	0.28	0.011	0.010	0.48	0.50	0.20	4 to 7	Packard Motor Car Co.
		0.33	0.86	0.31	0.009	0.012	0.46	0.46	0.21	8	Wright Field
3b	S.A.E. 4140	Normal expectancy of standard analysis.....									Climax Molybdenum Co.
4a	A.M.S. 6322 [NE 8739]	0.43	0.82	0.31	0.015	0.012	0.46	0.50	0.24	7	Wright Field
		0.40	0.94	0.28	0.016	0.028	0.57	0.48	0.26	6 to 7	Packard Motor Car Co.
		0.42	0.85	0.29	0.011	0.015	0.50	0.51	0.23	5 to 7	Packard Motor Car Co.
4b	S.A.E. 4640	Normal expectancy of standard analysis.....									Climax Molybdenum Co.

Tensile Properties

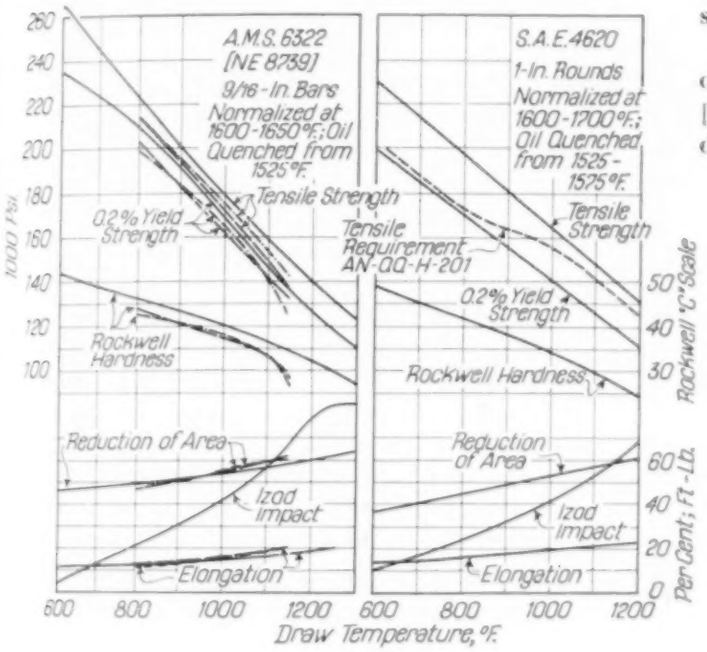
The properties usually used in design are those determined by tensile, compressive, shear, impact and fatigue tests. Values from the tensile tests can be used as satisfactory criteria for compression and shear. Impact is used as a measure of the notch sensitivity of the steel and may be affected by low temperatures. (Many tests have been made on the "standard" steels at sub-atmospheric temperatures and none has indicated an appreciable effect on the tensile and fatigue properties; therefore, such tests are not included in the laboratory work at the Materiel Center.)

The tests at the Materiel Center were conducted in accordance with Federal Specification QQ-M-151, General Specification for Inspection of Metals, on specimens heat treated at about 0.520-in. diameter.

Properties as determined on heat treated

tensile pieces (quenched and drawn at various temperatures) by the Materiel Center and by the laboratories listed in the footnote are shown in Fig. 1 to 4. Curves for some "standard" steels are placed alongside, in order to judge quickly the comparative properties of the alternate steels tested. Actual chemical compositions of the steels tested are listed in Table II.

Fig. 4a — Three Heats of A.M.S. 6322 Steel [NE8739] as Tested at Wright Field (Full Line) and by Packard Motor Car Co. Fig. 4b — A Comparable "Standard" Steel S.A.E. 4640



For the "standard" steels, the values given in Army-Navy Aeronautical Specification AN-QQ-H-201, Process for Heat Treatment of Steels (Aircraft), are shown as a dashed line. Certain related tendencies between the standard steels and their alternates will be observed on comparison of the curves; however, it should be remembered that the variability, heat to heat, of the standard steels is appreciable and that the variability of the new steels may be somewhat greater due to the lower alloy content. [Observed values, therefore, may straddle the indicated lines.]

Tensile properties of the alternate steels compare favorably with the standard steels. This is true even though the A.M.S. 6320 [NE8735] steels tested by Packard and at the Materiel Center are at the low side of the carbon range.

A quite definite yield point was observed in the testing of both A.M.S.6320 [NE8735] and A.M.S.6322 [NE8739] after drawing at 1000° F. However, in all instances the yield strength at 0.002 in. per in. was indicated on the charts.

Notched-Bar Tests

Impact properties were determined for the various draw temperatures in the steels tested at the Materiel Center. As with the tensile values these steels showed great similarity to the corresponding standard steels.

Some plain carbon steels lose notched-bar impact strength rapidly with decreasing temperature. Steels 6320 [NE8735] and 6322 [NE8739] were tested after two representative heat treatments. The results are shown and compared

Fig. 5 — Notched-Bar Tests at Decreasing Temperatures. At left are alternate and standard steels after heat treatment to 150,000 or to 200,000 psi. ultimate strength; at right are tests of several standard steels all medium hard, and of NE8630 at similar hardness

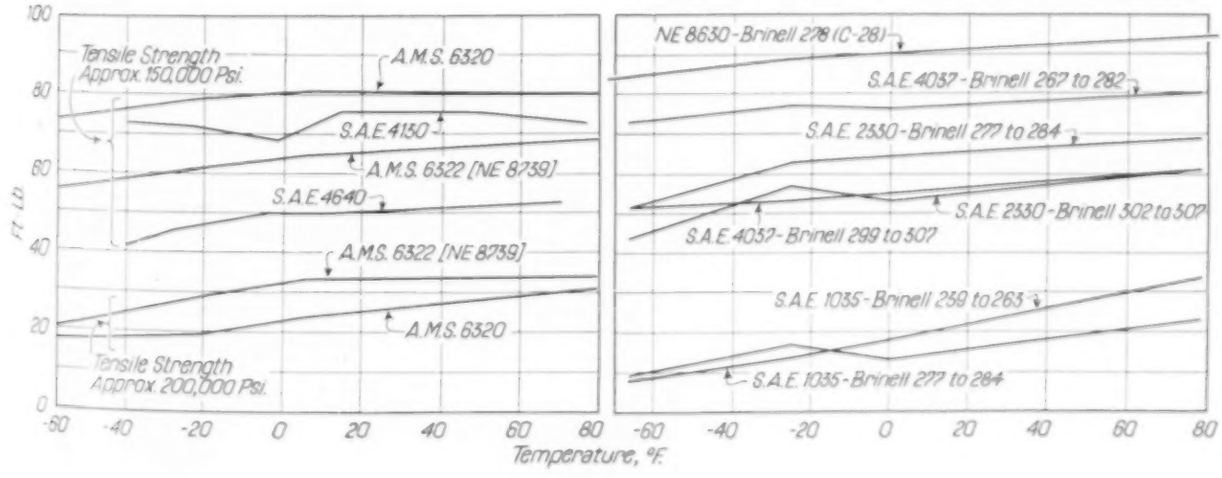

Tensile Strength Approx. 150,000 Psi.
A.M.S. 6320
S.A.E. 4130
A.M.S. 6322 [NE 8739]
S.A.E. 4640
A.M.S. 6322 [NE 8739]
A.M.S. 6320
Tensile Strength Approx. 200,000 Psi.
Ft.-Lb.
NE 8630 - Brinell 278 (C-28)
S.A.E. 4037 - Brinell 267 to 282
S.A.E. 2330 - Brinell 277 to 284
S.A.E. 2330 - Brinell 302 to 307
S.A.E. 4037 - Brinell 299 to 307
S.A.E. 1035 - Brinell 259 to 263
S.A.E. 1035 - Brinell 277 to 284
Temperature, °F.

Table III — Tensile Data on S.A.E. 4037 Bolts

Nominal Size	Root Diameter	Maximum Load (Average)	Minimum Load Specified Spec. AN-B-3
¼ x 28	0.209 in.	5,480 psi.	4,080 psi.
⅜ x 24	0.324	12,640	10,100
½ x 20	0.436	23,590	18,500

Table IV — Double Shear Data on S.A.E. 4037 Bolts

Nominal Size	Shank Diameter	Maximum Load (Average)	Minimum Load Specified Spec. AN-B-3
¼ x 28	0.2465 in.	9,316 psi.	7,360 psi.
½ x 20	0.4967	33,200	29,400

Bolts passed a bend test of 180° over own diameter.

with similar tests on some of the older steels in Fig. 5. Both steels retained their impact resistance well. As with most other tests reported here, the values are for one heat only and do not indicate the variability which will occur.

Tests on Aircraft Bolts

Miscellaneous tests have been made to determine the suitability of Specification AN-S-9 steel (S.A.E. 4037) for use in aircraft bolts. Tests at the Materiel Center for shear and tensile values conducted on such bolts fabricated by the Lamson & Sessions Co. indicated that this steel was suitable for bolts to ¾ in. diameter inclusive. Results are shown in Tables III and IV.

Curtiss-Wright Corp., Airplane Division, states that bolts and test bars of Amola 269, whose composition approximates that of AN-S-9 steel, conform to the requirements of Specification 29-59B, Aircraft Bolts (new Specification AN-B-3).*

Bars of A.M.S.6280 (NE8630) steels were heat treated by the National Lock Co. in the sizes used for bolts and sent to the Materiel Center for testing; results are given in Table V. Low temperature impact tests were also made on bars from Union Carbide and Carbon Research Laboratories and the results are plotted in Fig. 5b. Analysis of the A.M.S.6280 steel [NE8630] was: 0.304% carbon, 0.80% manganese, 0.25% silicon, 0.014% phosphorus, 0.015% sulphur, 0.42% nickel, 0.49% chromium and 0.22% molybdenum.

*Editor's Note — See also the article and data sheet on Amola Steels on pages 386 and 389.

Hardenability

The above data have shown that, when tested in the form of small bars, the physical properties of the alternate steels are comparable with those of standard steels. However, for some uses it is necessary that these properties be developed throughout fairly large sections. The best measure of the ability to do this is the Jominy hardenability test; with this apparatus it is possible to eliminate all variables except those of heating procedure and inherent hardenability. For this reason hardenability tests have been made in this manner on some of the steels which have been used and some of the comparable alternate steels, and the results are plotted in Fig. 6. It will be noted that in the case of S.A.E. 4130 and S.A.E. 4140, where more data are available, the hardenabilities have been shown as bands bounded by actual curves observed in testing. The width of these bands for well-known "standard" steels indicates that the variability to be expected in the newer steels need not be a serious difficulty in their use. All the steels were heat treated in a

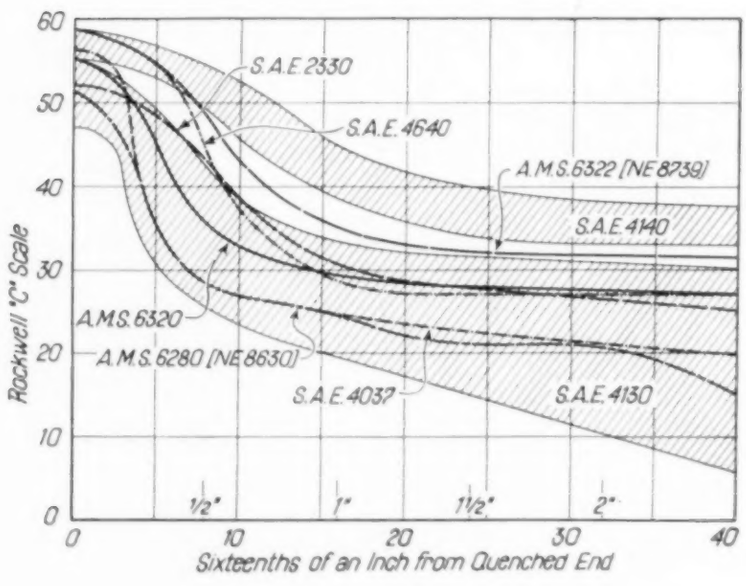


Fig. 6 — Jominy Hardenability Tests on a Few Alternate and Standard Steels of Following Analyses:

Steel	C	Mn	Si	P	S	Ni	Cr	Mo	
S.A.E. 4140	0.44	0.75	—	0.014	0.013	—	1.05	0.20	(upper limit)
	0.40	0.73	—	0.014	0.011	0.27	0.96	0.21	(lower limit)
S.A.E. 4130	0.34	0.76	0.22	0.016	0.017	0.29	0.93	0.22	(upper limit)
	0.25	0.50	0.18	0.010	0.010	0.05	0.94	0.23	(lower limit)
A.M.S. 6322	0.43	0.82	0.31	0.015	0.012	0.46	0.50	0.24	
S.A.E. 4640	0.41	0.69	0.30	—	—	1.86	—	0.25	
S.A.E. 2330	0.29	0.61	—	—	—	3.41	—	—	
S.A.E. 4037	0.40	0.53	—	—	—	0.12	0.14	0.21	
A.M.S. 6320	0.33	0.86	0.32	0.009	0.012	0.46	0.46	0.21	
A.M.S. 6280	0.30	0.80	0.25	0.014	0.014	0.42	0.49	0.22	

Table V — Tests of A.M.S. 6280 [NE8630] Bolt Bars

	Size of Round			Specification Requirement
Nominal Actual	¼ In. 0.203	½ In. 0.433	¾ In. 0.667	
Draw temperature *(a)*	1100° F.	1050° F.	1025° F.	
Ultimate strength *(b)*	134,600	134,200	129,400	125,000
Yield strength *(b)*	125,500	123,900	116,000	96,000
Elongation in 4D *(b)*	20%	18.5%	17%	17% min.
Reduction of area *(b)*	Not measured		61%	50% min.

(a) All bars quenched in oil at 100 to 110° F. from 1525° F.
(b) Average of four values with maximum deviation of 4%.

manner which appeared suitable to develop their maximum hardenability and were normalized prior to testing.

In the steels which were tested at the Materiel Center, the grain sizes were found to be No. 7 and 8. The other steels whose hardenability is here reviewed were also fine grained.

Heat Treatment

The work which has been done on the effect of heat treating temperature and drawing temperature is summarized in Table VI, which shows probable temperatures required for certain tensile properties. Experience with A.M.S. 6320 [NE8735] and A.M.S.6322 [NE8739] at the Materiel Center has indicated that the quench temperatures may vary over a range from 1475 to 1600° F. without affecting the hardenability. In these steels the grain coarsening range was found to be 1750 to 1800° F. Thus it appears to be possible to select a quenching temperature which will develop the maximum hardenability in all heats for each manufacturing operation.

With respect to the drawing temperature the situation is less simple. Even within the small number of heats here presented, there is much variation in the draw temperature necessary to develop a particular tensile strength. This probably is due in some degree to differences in laboratory procedure. The general practice for heat treating these steels should follow the recommendations in Specification AN-QQ-H-201.

Summary

The laboratory tests indicate that the steels are suitable alternates for many of the aircraft steels which have higher nickel and total alloy contents. For example, steels conforming to Specification AN-S-9 were found suitable for bolts and screw machine parts ¾ in. and under in shank diameter.

Aeronautical Material Specifications 6280, 6320 and 6322 cover steels which are satisfactory for aircraft parts in which the desired physical properties can be obtained by heat treatment, provided the requirements for model tests have been satisfied.

Table VI — Heat Treating Temperatures, °F., for Alternate Steels

Specification	Source *(a)*	Temperatures			Draw Temperatures for Tensile Strength of				
		Normalizing Air Cool	Annealing	Oil Hardening	100,000	125,000	150,000	180,000	200,000
AN-S-9 (S.A.E. 4037)	A *(b)*	*1600*	*1525 to 1575*	*1525 to 1575*	*1125*	*1000*	*875*	—	—
A.M.S. 6280 (NE8630)	R	*1650*	*1525 to 1575*	*1525 to 1575*	—	*1150*	*1020*	*800*	*690*
A.M.S. 6320	W	1650	—	1550	—	1220	1070	900	790
	P	1600	—	1550	—	—	1050	890	800
	(b)	*1650*	*1525 to 1575*	*1525 to 1575*	—	*1200 to 1220*	*1050 to 1070*	*880 to 900*	*780 to 800*
A.M.S. 6322	W	1650	—	1525	—	1260	1100	1000	900
	P	1600	—	1525	—	—	1110	960	870
	P	1600	—	1525	—	—	1120	970	870
	(b)	*1625*	*1500 to 1550*	*1500 to 1550*	—	*1240 to 1260*	*1100 to 1120*	*970 to 1000*	*870 to 900*

(a) Sources of information: A, Specification AN-QQ-H-201, Amendment 1.
R, Republic Steel Corp., Laboratory Report No. 5984-11, April 14, 1942.
P, Packard Motor Car Co., Report RR-48, April 29, 1942.
W, Materiel Center data.
(b) Recommended temperatures in italics.

Bits and Pieces

Case Depth Defined (?)

THE EDITOR'S "dumb question" ("What is the meaning of the term 'case depth' and how do you measure it?") was possibly asked to incite another note to METALLURGICUS' OWN PAGE. (By the way, if you like it, send in your own notes; there's a book of your choice for reward!) From a purely practical man's viewpoint case depth is

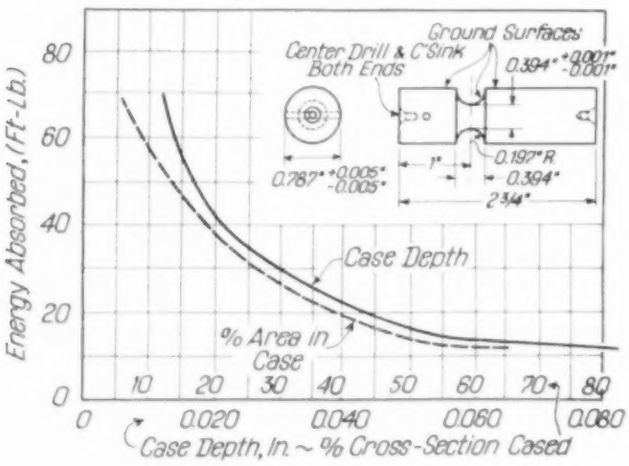
1. The part of a carburized low carbon steel part hardenable to C-50 or better.
2. The part containing 0.45% carbon or more (microscopically estimated).
3. The case that etches dark in the soft condition or
4. Etches light after hardening.

All four of these, in my experience, are closely similar, and represent the portion of the hardenable surface which is effective or useful for such purposes as warrant the carburizing treatment.

METALLURGICUS

Impact Specimens for Hardened Steel

It is difficult if not impossible to obtain impact values from Izod specimens carburized and hardened to Rockwell C-60. Unnotched round bars have been used but localization of the break is almost impossible. I find that a grooved specimen, as illustrated, localizes the break and gives values of sufficient magnitude to record variations in case depth, grain size and case microstructure. The dimensions are such that the bar is 2 cm. diameter and the groove 1 cm. at root. Groove was ground with Radiac 9A-150I grinding wheel.



An example of the effect of the case depth is shown in the graph, where the full line is the case depth and the dotted line is the percentage of the cross-section at the root which is cased. Material was A 2317, grain size 6, carburized at 1700° F., quenched in oil, quenched again from 1520° F. and tempered at 325° F. Hardness was Rockwell C-63.

The case depth was measured on a polished microspecimen lightly etched with nital. The specimen is held up to a light bulb and the division between the high hardness case and the softer core is marked with a sharp lead pencil — or preferably a diamond pencil — and then measured under a standard Brinell glass. This gives an accurate measurement to about 0.50% carbon. (A. S. JAMESON, Works Metallurgist, International Harvester Co.)

Figuring Reduction of Area

Ten tension tests are now being made for every one that was made in the piping days of peace. Figuring the reduction of area is something of a chore, alleviated only by extensive tables, *unless* the following short cut is known, making use of the formula

$$\text{R.A.} = 100\left[1 - \left(\frac{d}{D}\right)^2\right]$$

where D is the original diameter of the test piece and d is the diameter of the neck after fracture.

One setting on an ordinary slide rule is sufficient. Its top face is, of course, graduated in four scales, A at top, B and C on the slide and D below.

Procedure: Note D on Scale D; set d above it on sliding Scale C; read Scale B below either of the 10 marks on Scale A; subtract this from unity, and you have the reduction of area.

Example: $D = 0.507$ in. $d = 0.362$ in. Divide 0.507 (Scale D) by 0.362 (Scale C) and 0.51 is read on Scale B against 10 on Scale A. In other words 0.51 equals $(d \div D)^2$. $1 - 0.51 = 0.49$ or 49% reduction of area. (N. J. ALLEMAN, Asst. Prof. of Engineering Materials, University of Illinois.)

Use of High Lead Solders

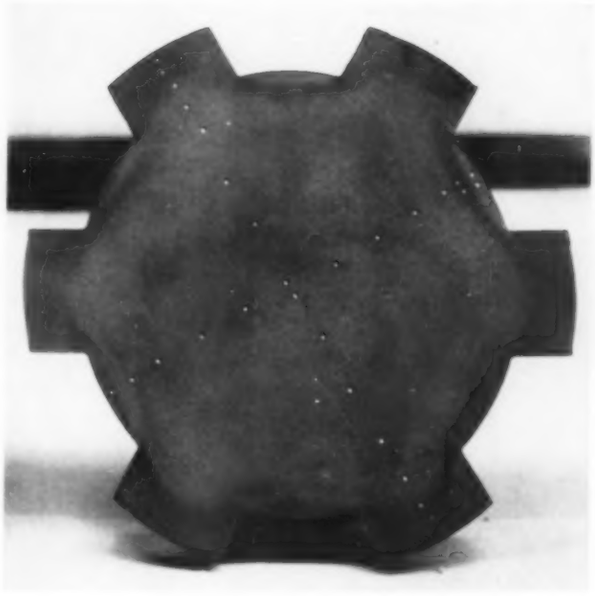
Solders low in tin are deficient in spreading quality. However, they are quite successful if a proper gas-air flame is used rather than a soldering iron. This practice involves the use of small pointed gas fires which heat both the work and the solder at points of soldering. When using a solder containing 97.25% lead, 2.5% silver and 0.25% copper, it has been found that natural gas fires do not produce satisfactory spreading. By adding hydrogen to the gas-air mixture, this solder can be made to spread satisfactorily. Also, this practice has been applied to a solder containing 95% lead and 5% tin with satisfactory results.

Most artificial gas contains hydrogen, and it has been found that artificial gas-air fires can be so adjusted that some of the high lead solders will spread. (Lamp Department, General Electric Co., Cleveland.)

Soft Roots Corrected

Facing a shortage in alloy steel, we started making 3-in. spline shafts from S.A.E. 1045, hung them from one end in a Hevi Duty forced convection furnace and heated them scale-free in prepared atmosphere. We hardened vertically from 1500° F. in 10% brine for 60 sec., then in oil till cool, but we got soft areas at the root of the splines. On sectioning and etching, a peculiar hardness distribution was shown. In the accompanying photograph light etching areas are soft, and dark areas hard; at upper right, the first two Rockwell readings are C-29, the next two C-52, and the next one C-35.

We theorized as follows: In the initial brine quench the outer skin, even in the roots, transforms almost instantly to martensite at about 200° F. Immediately behind this skin there is an area which, in cooling, barely "cuts the nose of the S-curve" and begins to transform at about 700° F. During this period heat is being supplied from the body of the hot metal to the



outer skin, which in the meantime has been insulated by a pocket of steam in the roots of the splines. The surface there is consequently tempered to Rockwell C-29, the adjacent layer hardening to Rockwell C-52. (It is probable that the latter remains as under-cooled austenite till the shaft is transferred to the oil.)

In this particular case adoption of a spray quenching fixture solved the problem. Relatively uniform surface Rockwells of C-50 to 55 are now easily obtained all over the splines and distortion is within grinding allowances. By timing the brine quench to 1 min. no cracking has been experienced. (L. F. TRAIN, Metallurgist, John Bertram & Sons Co., Ltd.)

Finding a Little Iron
in a lot of copper

As little as 0.05% Fe can be quickly and simply detected qualitatively in a copper solution (from which any Sn, Pb, Al, and Mn has been precipitated) by adding hydroxylamine sulphate or chloride (to form a colorless complex ion with the copper) and then adding ammonium hydroxide to precipitate the iron.

Procedure — To a slightly acid solution of copper and iron add 5 g. hydroxylamine sulphate and stir until dissolved. Then add ammonium hydroxide (1:1) until basic (pH about 8). Allow to stand for 15 min. and then observe whether or not an iron precipitate in the form of the hydrous oxide is there. (ALBERT C. HOLLER, Chemist, United States Metal Products Co.)

Tool Hardening; Practice, Not Theory

By Robert C. Stewart
Metallurgist
Apco Petroleum Products, Ltd.
Toronto, Canada

TOOL HARDENING is only one aspect of heat treatment. Of course, other metal articles besides tools are heat treated, and tools (or toolsteel) may be heat treated for other purposes than for hardening, but any discussion of as large a subject as heat treatment must be limited in scope, so this will be limited to some practical aspects of tool hardening.

Heat treatment is defined in Metals Handbook thus: "An operation or combination of operations involving heating and cooling of a metal or alloy in the solid state for the purpose of obtaining certain desirable conditions or products." The heat treatment we will discuss is for the purpose of securing that combination of hardness, toughness, and abrasion resistance suitable for metal working tools, and this involves a heating to above the so-called critical temperature, where a revolutionary change occurs in the microstructure of the metal, a suitably rapid cooling to trap this unstable internal structure in the cool, strained, and therefore hardened tool, and a moderate reheating or tempering to relieve enough of this internal strain so the tool is less brittle yet not much softer.

Tool hardening, consequently, consists of three phases, first a heating, next a quenching, and third a tempering. Equipment and good practice for these three operations will now be described briefly.

Heating — In order to expedite work, the rate of heating is often dangerously pushed to the limit, and this can cause damage, especially in the larger blocks of metal. In good practice it is necessary to consider not merely the *average* rate of heating, but the rate that is desirable, or permissible at each stage of temperature rise, and as a matter of fact the rate of heating is seldom constant, and actually decreases as the work approaches the temperature of the furnace or surrounding medium.

The actual heat absorbed when a piece of metal is heated to a given temperature is equal to the heat content of the mass at that temperature, i.e., about 300 British thermal units per pound at 1800° F. Of course, only a small portion of the heat liberated in a fuel-fired furnace is absorbed by the metal — most of it goes out the flue in hot gas. An electrically heated furnace of "cyclone" type is most efficient, where the atmosphere is circulated in a tightly closed system over hot resistors, through the work and back again.

If a piece of steel, initially free from internal stress, is heated uniformly no internal stress will be set up. However, if the heating is not uniform so that different parts of a piece acquire widely different temperatures at any time, the hot portions expand at a more rapid rate than the cooler portions, and internal stresses will be set up which will cause distortion, and in a brittle or large mass of metal may cause rupture during the heating-up period. Common examples are the cracking of the high

carbon-cobalt type of high speed steel during the initial heating of the annealed material for hardening, or during the reheating of unannealed high speed steel. (Stress relief during the early stages of heating will be described later when discussing tempering.)

Uniform heating is favored by uniform and slow application of heat, and the high thermal conductivity of the metal being heated. Slow application of heat means the furnace must not be tremendously hotter than the work entering it, and is the reason for preheating high speed tools before introducing them into the high heat furnace.

Holding at Heat — Usually a certain more-or-less definite period is required at the highest temperature at which a piece is heated, sufficient for the entire piece to come to a uniform temperature, as well as long enough for desired chemical and physical changes to take place internally, such as solution and diffusion of the carbides. When heated through the critical temperature range (1300 to 1400° F.) the microscopic particles of iron carbide which exist in the annealed steel dissolve in the surrounding iron very rapidly; some of the more complex carbides (like those containing vanadium or chromium) require much higher temperature and longer time — say 1750° F. (even 2350 for the tungsten carbides in high speed steel).

Overheating must be avoided, for it involves rapid "grain growth" and consequent embrittlement. It is well known that a steel acquires a new and very fine grain size when heated just through the critical. Higher and longer heats tend to cause "grain growth", that is, the average grain size gets larger. Properly made toolsteels generally contain elements that offset this tendency until the steels are grossly overheated — say, for a long time at 1750° F. and above.

Furnaces — Furnace equipment is well standardized along the following general lines: If heating for tempering is below 1000° F., circulating air furnaces or salt baths are indicated. For heating up to 1750° F. electric resistor furnaces or oven type fuel-fired furnaces are used, with the following general efficiencies: Oven type under-fired will heat 35 lb. per sq.ft. hearth area per hr. Side-fired types generally heat about 70 lb. per sq.ft. per hr. Direct-fired types heat 100 lb. per sq.ft. per hr. For temperatures of 2300° and over either fuel-fired or Globar type of electric resistance furnaces are used.

Surface Protection — The surrounding atmosphere, or heating medium, is important insofar as it affects the rate of heating, and causes or prevents chemical changes such as scaling, oxidation, or carburization to proceed from the surface inward toward the center of the piece. The reactions between furnace gases and hot steel are so complicated that often the best way is to exclude the gases entirely by heating the tool in melted lead or inert salt. For small installations, properly adjusted fuel-fired furnaces with slightly oxidizing atmospheres are satisfactory. Some allowance must be made for scaling, and while carbon is also lost from the surface of the steel (tending to cause "decarburized" or soft bark), the steel normally oxidizes at a faster rate than it decarburizes, and will quench out hard if the scale shells off during the operation.

For materials like high carbon-chromium steels, copper paints such as Sel-car may be used to seal off the surface and prevent decarburization. Packing the tools in protective cast iron chips is a well-known device. Small muffles cut from carbon blocks (Sentry "diamond" blocks) also generate a protective atmosphere.

For more expensive installations incom-

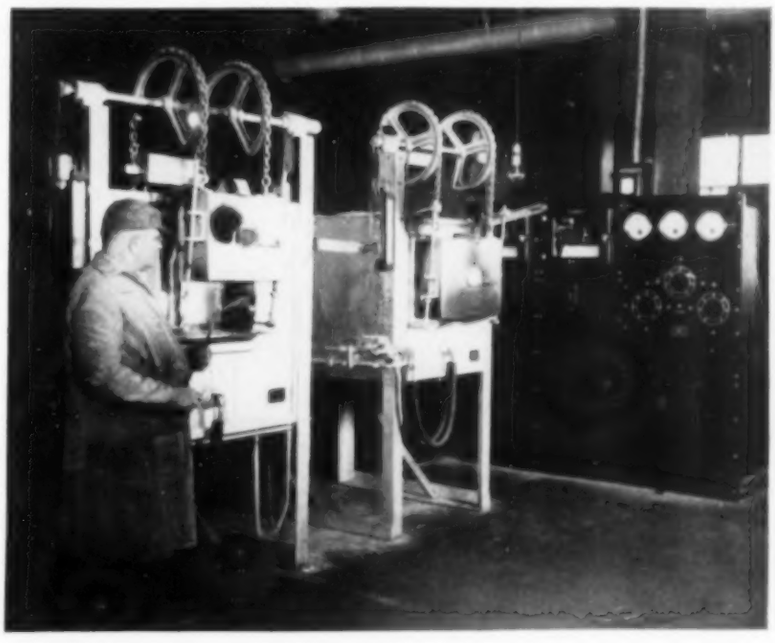


Fig. 1 — A Pair of Hayes Furnaces for Heating Tools in a Protective Atmosphere

pletely burned gas may be introduced into a nearly gas-tight muffle in such amount and composition that the gas is in equilibrium with the material being treated, or nearly inert to it. This type of atmosphere and its composition are largely dependent on local gas conditions, and manufacturers of equipment are well able to advise. The Hayes "Certain Curtain" furnace (see Fig. 1) is heated by electricity, and a pre-burnt gas mixture is admitted through a slot in the sill just inside the door. This gas-air mixture is prepared in a separate chamber cut in the refractory lining below the slot, and suitable valves and gages allow various combinations to be set and maintained. The Lindberg "Hydrizing" furnace actually hardens certain types of steel and brings them out bright and scale-free, by using an atmosphere made from dissociated ammonia and carbon monoxide, the latter being generated from hot charcoal in another chamber in the furnace setting. As shown in the accompanying sketch, the hot work is quenched direct from the furnace through a chute submerged in the coolant, so while the work is hot it is entirely out of contact with air. Still another successful device is the Westinghouse "Ammogas" furnace for hardening the air hardening high carbon, high chromium die steels free of scale and decarburization. Preheating (and cooling) is done in the front end of the muffle proper, which is a long chamber set on an incline. (See Fig. 3.) Unfortunately, this furnace works only on steels that harden when cooled at a very slow rate — the "air hardening" steels.

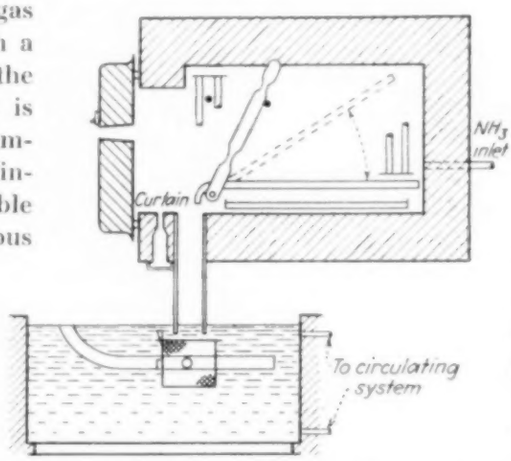


Fig. 2 — Diagram of Lindberg Furnace With Inlets for Protective Atmospheres and Device for Quenching Articles Without Exposure to Oxidizing Surroundings

Liquid Baths — For rapid heating of small parts lead baths are very good, as also are salt baths. The following considerations might be of interest: Lead compared to salt mixtures is higher in specific gravity, higher in initial cost by volume but lower in cost by consumption; it is also higher in thermal conductivity, and lower in specific heat, thus causing greater temperature drops when cold work is introduced; for the same reason lead also requires less fuel to bring a cold pot up to heat. Lead also absorbs less heat when melting — that is to say, it has a lower "latent heat of fusion" — this causes it to chill heavy layers of solid lead on cold work just introduced (although such layers are more common in salt baths due to their much lower thermal conductivity). Molten lead needs a charcoal cover, but does not pit the work nor corrode as do some salt baths. Lead will not stick to the work if it is mildly preheated and dipped in brine; the salt left when the water evaporates forms a film which keeps the lead away.

When work is removed from a salt bath, a continuous film of salt is dragged out on the work, effectively sealing out the atmosphere during the transfer to the quench. This film readily washes away during water quench, but constitutes a considerable loss of material. Lead baths do not absorb moisture, while all salts do to some extent, and thus sometimes troublesome explosions occur when adding more salt to a hot bath — this is avoided, of course, by oven drying the new salt.

Ordinary pig lead is satisfactory for a bath, but if tin or nickel is alloyed with it the lead will stick to the work. Owing to its solubility in lead, nickel thermocouple tubes should be avoided. Nichrome pots are generally best for high temperature operation.

Contrary to popular opinion a lead pot with suitable charcoal cover does not give off objectionable vapors if electrically heated; however, if fuel-fired, any lead that may splash into the combustion chamber will fume, but since a hood is generally used to remove products of combustion from this type of furnace, the same hood will carry off objectionable lead fume.

Cooling the Work

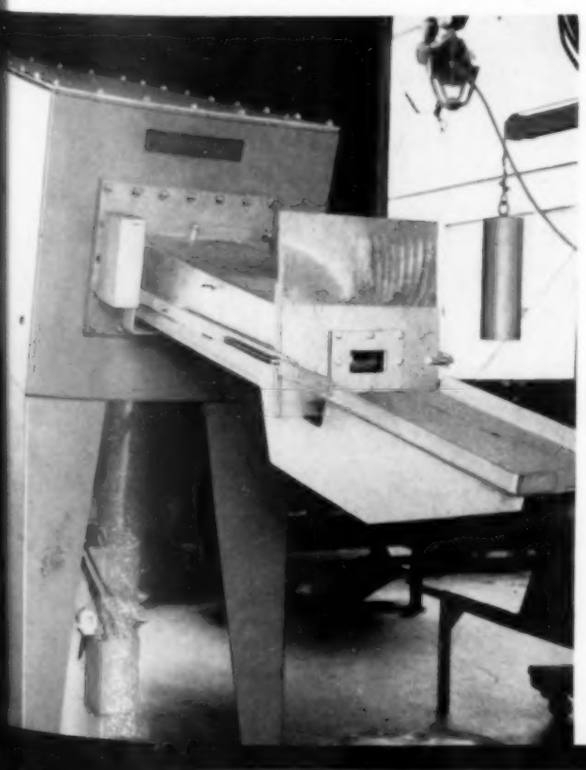
In a pure metal like copper or a single phase alloy like cartridge brass, the only phenomena that take place during heating and cooling are release of work hardening strains, recrystallization, or grain growth. Heat treatment of such materials is usually for the purpose of softening, and the rate of cooling is

relatively unimportant, and therefore is determined largely by convenience.

In steel, however, the constitution of the material is different. It comprises two distinct fundamental substances, iron and iron carbide — more or less pure. The solubility of iron carbide in the iron is greater at maximum temperature than it is at room or working temperatures, and the rate of cooling is of the greatest importance in determining the eventual structure which is the result of the heat treatment. Very slow cooling permits full development of constitutional stability (a stable atomic arrangement) at low temperature, while rapid cooling may preserve the structure which existed at the high temperatures, but now in an unstable condition in the cold metal.

It is impossible here to give even a cursory account of the hardening reactions that take place — in fact, the real essense of hardening, what really makes a material hard or soft, is as yet unknown. However, enough has been discovered within the last 20 years of work on the problem to emphasize the paramount importance of a high cooling rate during quenching — at least through the region just below the "critical temperature", say from 1300 down to 1000° F., where the tendency is greatest for the steel to "transform" from its state of solid solution to a state where the ferrite and cementite are separate entities, even though intimately mixed. Even the ancient smith knew that quenching rate was of prime importance, and treasured his "secret" quenching baths, often a fearful and wonderful concoction of purely psychological virtue.

Fig. 3 — Westinghouse Furnace for Treating Air Hardening Steels in Cracked Ammonia. Parts are loaded in a tray, pushed up into front end of muffle, door closed, muffle purged and tray moved further up into the hot region. Cooling (and hardening) is done by bringing tray back to front end of muffle



Coolants — Water is the most widely used coolant, and is very effective if used as a spray, but has the objection that the cooling rate changes rapidly with the temperature of the bath. Also used extensively are sodium hydroxide solutions, brines of different strengths, oils, molten salts, lead, air blasts, or still air.

Sodium hydroxide solutions provide an extremely rapid quench which "takes hold" very quickly at high temperature, and continues to cool very rapidly right down to room temperature — to below 300° F. — thus forcing the steel to "transform" at low temperature where the best conditions exist for the hardening reactions to occur. However, these solutions are very corrosive and somewhat dangerous to work with, as scale is violently thrown off during the quench, and they deteriorate rapidly due to absorption of carbon dioxide from the air. (SAFETY NOTE: Have a bottle of vinegar and pad of bandage in a handy cabinet, so if a drop of caustic splashes into a man's eye, it can be neutralized quickly with the vinegar.)

Brine — 5 to 10% solutions of salt in water are the most widely used of the liquid quenching media, and although corrosive to metal tanks, they are not dangerous to the operator. When salt is dissolved in water, the dissolved gases are thrown out of solution, and escape. (Did you ever see a dash of salt liberate gas from beer?) Freedom from dissolved gas in the quench helps eliminate soft spots which are usually formed when the gas being thrown out of solution by heat from the work forms adhering bubbles, keeping the liquid away.

As the brine solution evaporates at the hot surface during the quench, solid salt is deposited and this salt film instantly melts, actually explodes and blows off scale in exactly the same manner that the salt added to the roughing stands of a rolling mill will help free the scale. Thus the hot metal surface is bare, and cools the faster for being free of any insulating scale. Although not as fast as sodium hydroxide or sprays, brine is much faster than water. (If the work is heated in a salt bath, running water is generally the best quench, as the salt dragged out by the work rapidly changes the composition of the bath.)

Oils — Factors affecting the result from an oil quench are the temperature of the oil, rate of flow relative to work, and, most important, the cooling rate of the oil in question. The only

effect the *type* of oil will have on the work quenched in it is the ability of that oil to cool the work at the correct rate, from 1300 down through the critical region to 1000° F. and thence to about 300° F. Oils must also have a high flash point to avoid fires, and form no excessive sludge by "cracking" under the action of heat. Oil should have a high distillation range, and be free of light fractions that rapidly distill off and thus alter composition and cooling rate. Some quenching oils have added animal fats which are claimed to stabilize the oils, and make them "wet" the work better. In any liquid bath agitation may be manual or by pump. An outboard stirring device is very cheap and effective.

Cooling Power of Baths — Once it is recognized that the only thing a quenching bath can do to steel is to cool it, and that all steels have substantially the same heat capacity and transmission rates, it becomes possible (if you are a good enough mathematician) to compute the temperature at any position within a round bar at any time during a so-called "ideal quench" of infinite cooling power — that is, one wherein the surface is *instantly* brought down to the temperature of the quenching medium. Likewise it is possible to determine the relative cooling power of any commercial combination of bath, temperature and circulation, "relative" to the cooling power of this "ideal quench". Marcus A. Grossmann and his assistants at Carnegie-Illinois Steel Corp. Research Laboratory have shown how this may be done by quenching three round bars of different steels in the given bath, sectioning the bars and measuring their hardness at various places, surface to center. Depth of hardening to a selected hardness value is then plotted and matched against a series of curves (reproduced in Metal Progress, 1941 Reference Issue, page 520), and the relative quenching power of the bath immediately read off.

Relative cooling power of common commercial baths is shown in the following table as "H values". It must be immediately emphasized that there may be a valid reason for changing a quenching oil, such as smell, or cost, or stability, but the quenching power (cooling speed) will be about the same, no matter what oil is used. The only way to improve the "H value" of a quenching medium is to improve the circulation, or the quenching fixture, if any. (While water quenches are preferably cold — under 70° F. — it is well to operate oil-quenching baths warm, between 90 and 140° F.)

Circulation or Agitation	H Values for		
	Oil	Water	Brine
None	0.25 to 0.30	0.9 to 1.0	2
Mild	0.30 to 0.35	1.0 to 1.1	2 to 2.2
Moderate	0.35 to 0.40	1.2 to 1.3	—
Good	0.4 to 0.5	1.4 to 1.5	—
Strong	0.5 to 0.8	1.6 to 2.0	—
Violent	0.8 to 1.1	4	5

Quenching Fixtures are multitudinous in size and shape, for each one is designed for a certain part. Essentially, however, they are merely devices for bringing the cooling medium against the surfaces to be cooled in a direct and positive way, and traveling at such velocity as to sweep away all vapors as soon as they are formed, thus preventing a gas blanket from interfering with rapid heat transfer. Some fixtures may be arranged to *protect* certain areas

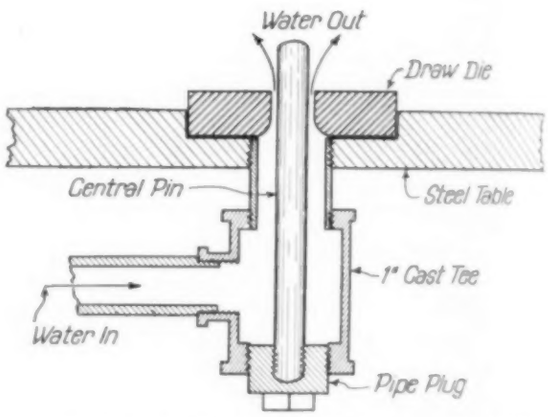
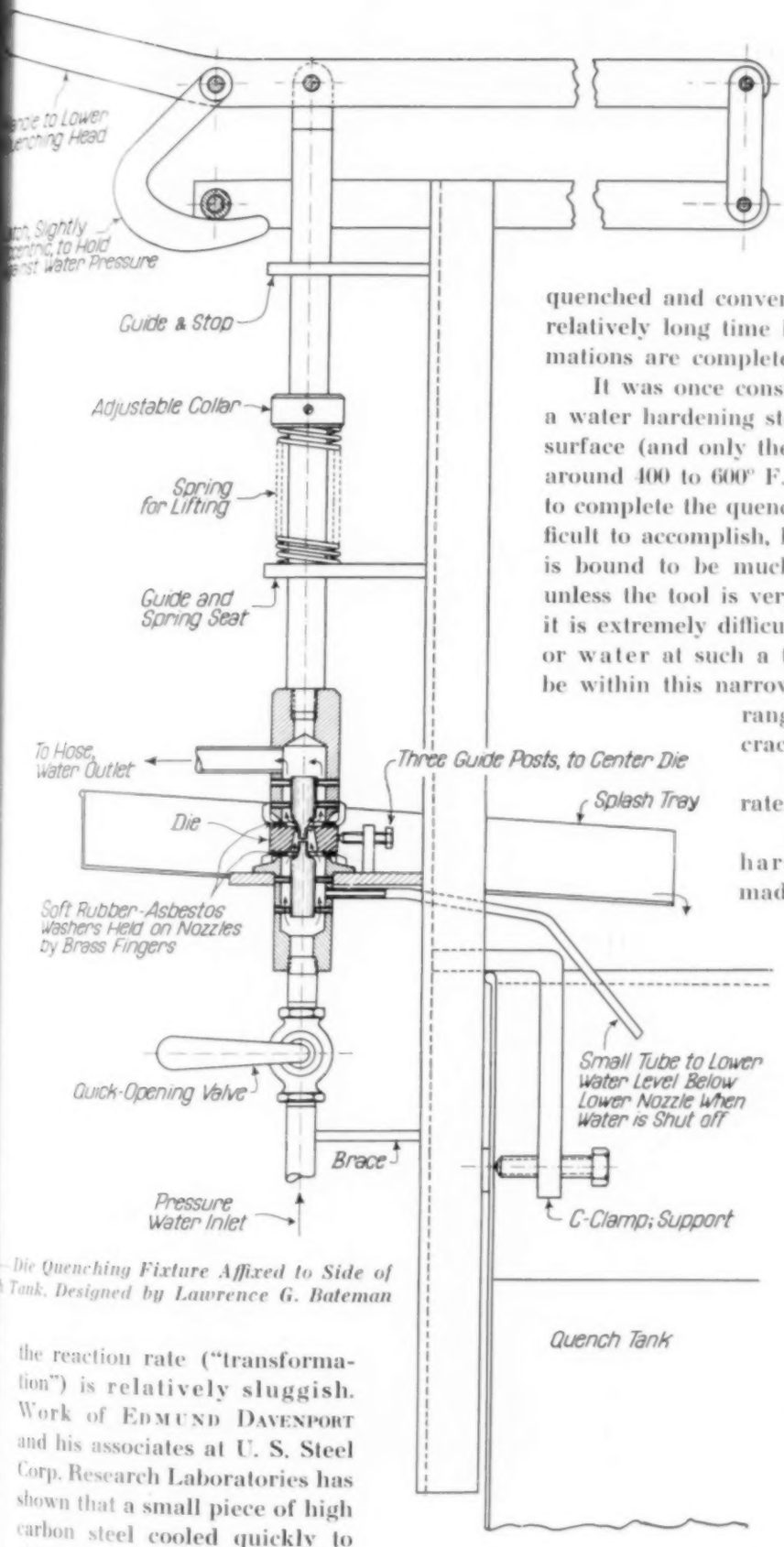


Fig. 4 — Simple Fixture for Hardening Die Center

and cool them slowly. Others clamp flat pieces under fairly high pressure to avoid warpage during quenching; others spin lengthy pieces on rigid bearings to maintain straightness. All must operate rapidly, for no time can be wasted between hot furnace and cold bath.

A simple device for quenching a draw die by cooling its center is shown in Fig. 4; the die would be held down by the operator's tongs, and he would simultaneously get a shower bath. A more elaborate fixture for doing the job more positively is shown in Fig. 5, as designed by Lawrence G. Bateman of Delamere & Williams Co., Toronto.

Interrupted Quench — As mentioned earlier, molten salt baths or molten lead are used for quenching high speed steel. Their cooling power, while small, is sufficient to "trap" the hardened microstructure in such highly alloyed tools, for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Guide and Spring Seat
To Hose, Water Outlet
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Splash Tray
Die
Soft Rubber-Asbestos Washers Held on Nozzles by Brass Fingers
Small Tube to Lower Water Level Below Lower Nozzle When Water is Shut off
Quick-Opening Valve
Brace
Pressure Water Inlet
C-Clamp; Support
Quench Tank

...Die Quenching Fixture Affixed to Side of ...h Tank, Designed by Lawrence G. Bateman

the reaction rate ("transformation") is relatively sluggish. Work of EDMUND DAVENPORT and his associates at U. S. Steel Corp. Research Laboratories has shown that a small piece of high carbon steel cooled quickly to about 450° F. and held at that temperature, as by quenching in a hot bath, will not start to transform for several minutes and will not be completely hardened for several hours. Steels hardened by this process, called "austempering", are frequently tougher than others quenched in cold baths because they have less internal stress. Small, spindly articles can also be hot quenched and conveniently straightened during the relatively long time before the hardening transformations are completed.

It was once considered good practice to snatch a water hardening steel from the quench when the surface (and only the surface) was cooled down to around 400 to 600° F. and transfer it to an oil tank to complete the quench. In practice this is very difficult to accomplish, because the outside of the tool is bound to be much cooler than the inside, and unless the tool is very small and uniform in shape it is extremely difficult to remove it from the brine or water at such a time that all sections would be within this narrow range (400 to 600°). If this range is missed, badly strained or cracked work will result.

A definite instance will elaborate this point:

A certain heat treater when hardening small lathe centers made from carbon toolsteel persisted in cooling the points only in water, allowing the hot shank to reheat the now quenched point and "draw it to a straw color", then finish cooling the center in water or oil. *Invariably the centers cracked.* What actually happened was that first the outer shell was fully cooled to room temperature and therefore fully hardened, while the core of the piece was still at some temperature above 400° F. and still not hardened (even though it was in a dormant state) and would fully harden later on, no matter what the final treatment. The heat escaping from this hot core served to temper the hard case, but later on when the core finally cooled to room temperature it transformed to the fully hard condition, with an accompanying *(Continued on page 448)*

Francis Cowles Frary

Researcher in Aluminum

Eminent American

Metallurgist

Photo by Parry, Pittsburgh

THERE HAS BEEN much talk about aluminum these days, but very little about the men behind this magic metal. Aluminum engineers are building new plants, erecting new machinery, and stepping up production every month. Aluminum research, which has been responsible for a great many improvements in aluminum metallurgy, has also received scant attention in the public prints.

The Aluminum Research Laboratories of the Aluminum Co. of America at New Kensington, Pa., deserve a large share of the credit for the intelligent planning which gave aluminum and its alloys their present prominent place in war. And, since FRANCIS C. FRARY has headed these laboratories for more than 23 years, much credit should go to him, too.

He, of course, would be the first to deny this. By nature one of the most modest of men, FRANCIS FRARY is a firm believer in the postulate that the surest success comes from coordinated effort rather than from the brilliance of a few individuals. He corroborates this statement by pointing to the compact and well-coordinated group of more than 200 scientists, technicians, and assistants over whom he presides.

If you want to take issue with him, you can call his attention to the many brilliant men who have helped him make the laboratories what they are today; those men are there because FRARY was there first. His own brilliance is both scholarly and practical. He has not only turned in a personally imposing record, but has had the ability to pick the men who have made the Research Laboratories outstanding.

FRANCIS COWLES FRARY was born in Minneapolis 58 years ago. There he entered the University of Minnesota and received the degree of Analytical Chemist in 1905. In 1906 the university made him a Master of Science. He spent a year of travel and study in Europe, and, on his return, joined the teaching staff, where the doctor's degree was conferred on him in 1912.

FRARY, whose robustness earned him a place on Minnesota's "Strong Men's Squad" in 1903, was intensely active at the university in his postgraduate years. During one year, for instance, he taught 15 courses! At times he simultaneously supervised work in a basement laboratory and in one on the third floor of the same building. His friends remember him "racing back and forth, dispensing electrochemical education three steps at a time".

In 1915, Dr. FRARY was offered a position as research chemist by the Oldbury Electro-Chemical Co. of Niagara Falls. There he became an authority on the production and handling of phosgene, and it was his experience in this subject that led the Government to select him, with Prof. D. J. DEMOREST of Ohio, to design and operate a phosgene plant at Edgewood Arsenal during the first world war. At its close Dr. FRARY left the army as a major in the chemical warfare service.

Just before he entered the service FRARY had accepted a position as director of research for the Aluminum Co. of America. When the Government asked for a priority on him, the Company agreed to wait until his tenure of military duty was over, rather than withdraw the offer and give the position to someone else. The executives were sure of their man and could afford to wait.

Major FRARY assumed his new duties in New Kensington in December, 1918, and his first task was to assemble a group of competent men for his research staff. His two present assistant directors, JUNIUS D. EDWARDS and H. E. BAKKEN, date from the spring of 1919. So do his chief chemist, HARRY V. CHURCHILL, and RICHARD L. TEMPLIN, chief engineer of tests, and several other members of the staff. Chief metallurgist E. H. Dix, Jr., was added a few years later.

FRARY's scope of activities has been broad, and he has a good grasp of every study in which he has interested himself. Just to mention the subjects of some of the 30 patents issued to him will give an idea of this breadth of interest. They include the electrolytic refining of aluminum, the electrothermal reduction of alumina, the manufacture of aluminum chloride, the electric annealing of aluminum sheet, the calcination of coke for electrodes, the calcination of bauxite, the proper type of molding sand for the casting of magnesium, the insulation of refrigerators, the removal of dross from aluminum, the refractory lining of crucibles, the development of a number of aluminum alloys, and an early method of hardening lead.

His keen analysis and discussion of the problems of the aluminum industry have always been very stimulating and have led to many discoveries by members of his staff. His broad interests have led him to learn German,

Norwegian, and French, and in addition, to read Italian and Swedish.

Such a man is bound to be invited to join any number of technical societies. You'll find his name on the rosters of the American Chemical Society, the American Society for Testing Materials, the American Society for Metals, the Institute of Metals, the American Institute of Mining and Metallurgical Engineers, and the Chemists' Club. He is a past president of The Electrochemical Society, and of the American Institute of Chemical Engineers.

At the 76th convention of the Electrochemical Society, which was held in New York three years ago, FRANCIS FRARY was presented with the Edward Goodrich Acheson Medal and prize, in recognition for his distinguished contributions to the field of electrochemistry.

Though he is far from being a legendary character, legends about him were bound to spring up in his long and active career. They are jocularly referred to as "Frary Tales", and they tell so much about the man that any biography of him would be incomplete without some reference to one or more of them. One of his associates at Minnesota heard that rumors were abroad that he had become engaged to ALICE WINGATE at the tender age of 20. FRARY turned and said indignantly: "If you wish to know about such things, please don't listen to rumors. If there's any truth to the matter, I'm the one who should know about it!" Two weeks later he bounded into his associate's laboratory and beamed: "What you heard is so! I can confirm the rumor. Alice and I are going to be married!" And so they were, back in 1908.

A "Frary Tale" which illustrates his point of view excellently — for he is an aluminum crusader just as much as anyone else in the industry — is the following about a lady who once remarked: "You know, Dr. FRARY, aluminum isn't good for applesauce." "Pardon me, madam," he replied, "what you mean is that applesauce isn't good for aluminum."

And that's no applesauce, as far as he is concerned. His real hobby — even though he admits playing golf "not wisely, nor too well, nor too often" — is aluminum and everything that concerns aluminum. Just made for him is a paraphrase of a saying from Terence, *Homo sum, et nihil humani alienum puto* ("I am a human being, and I can never be indifferent to anything human.")

He could well take it as his motto and say:

"Nihil alumini alienum puto."

"Amola" Steel

By Fred E. McCle
Metallurgical Engi
Chrysler Corp., De

AMOLA steels, Chrysler designation M.S. 241 to 291 inclusive, of which the S.A.E. and A.I.S.I. 4000 series is a part, are the result of an attempt to duplicate the physical properties of chromium-vanadium steels at a much lower cost and with the use of a domestic alloy.

It must be recognized that what the Chrysler Corp. has developed and knows as "Amola" steel is a melting and rolling practice, as well as an analysis. Therefore, the result was obtained by the use of molybdenum, manganese and silicon correctly balanced, together with a distinct change in melting practice and the introduction of new mill controls of the reduction per pass against loss of temperature. Heats are all produced in a fine-grained condition, with a definitely controlled grain coarsening temperature. This latter is of extreme importance in the carburizing grades. Deoxidation of the heat is carried much further than in most steels.

Carbon ranges in both electric furnace and openhearth steels are 5 points, 0.20 to 0.25; 0.25 to 0.30 and so on up to 0.65 to 0.70. In all steels the manganese is specified 0.70 to 0.90, silicon 0.20 to 0.30, molybdenum 0.15 to 0.25. Phosphorus and silicon are each held at 0.04% max. Incidental elements like chromium and copper are held to low limits, on account of their influence on hardenability.

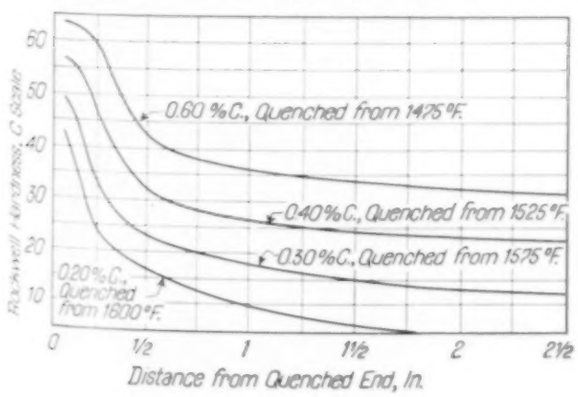
Hardenability or depth hardness is controlled by the amount and balance of molybdenum and manganese. This may sometimes be enhanced by raising the silicon also. By the proper selection of analysis and processing

(Carbon-Molybdenum)

practically any desired result may be obtained. Amola steels, therefore, become a complete series of general purpose steels which can be used throughout a long range from the low carbon, low hardenability carburizing grades, through the medium cold heading and forging grades, to the spring steels, ball and roller bearing steels and toolsteels for shear blades, chipping chisels, axes and razor blades. *These are all being produced commercially.* Plain carbon and chromium-vanadium are the only other general purpose steels, and they are subject to certain limitations.

Amola steel was first used commercially in 1933 for the automobile front coil suspension springs. This use was followed rapidly by its application to flat springs, axle shafts, spindles, steering parts, and finally to transmission and rear axle gears. In its development the various alloy steel mills in this country met and solved the production problems, and at the present time these necessary special practices are well known to the personnel.

End-Quench Hardenability Curves (Average Plots) for Carbon-Molybdenum Steels of "Amola" Series. (Chrysler Corp.)



It is interesting to note that its use in gears and other carburized parts is particularly indicated, because it is fine grained, and for this use the coarsening temperature is kept 50° F. or so higher than the normal carburizing temperature. Therefore, parts may be quenched directly from the carburizing furnace, and followed by the desired draw. This, of course, results in decided economy and less distortion.

Thousands of tons of the S.A.E. 4000 series have been used, particularly in the automotive industry, for the following typical purposes:

4023: Knuckle bolts, spline shafts, ball bolts.

4027 and 4032: Transmission and axle gears, the higher carbon for heavier teeth; the choice should be based on the desired core hardness.

4037: Cold headed bolts ⅜ in. and smaller.

4042: Bolts, ⅜ to 1 in.; steering arms; general forgings.

4047: Spindles, bolts over 1 in. diameter.

4053: Oil quenched gears.

4063, 4068: Coil and flat springs, axle shafts.

Numerous other analyses are in use for special purposes, particularly where large sections require high hardenability.

In using the carbon-molybdenum 4000 series it is advisable to specify carbon five points higher than S.A.E. 3100 steels normally used for the same part, and ten points higher than 4100.

Forging and machinability are similar to fine-grained 3100 and 4100 steels.

Heat treatment is best at temperatures 25 to 50° above the critical. Overheating is unnecessary and undesirable, for carbides go into solution rapidly, and high and prolonged heating increases cost and decarburizes the surface.

The age hardening factor is very low. Welding seems to be helped by the molybdenum.

Tensile properties of the steels containing 0.20 and 0.30% carbon, as drawn from average practice, are as shown in the table. 0.530-in. rounds were treated as follows: Normalized at 1600° F. for ½ hr., 0.505-in. standard tensile specimen prepared, heated to 1700° F. in cast iron chips for 1 hr. and quenched in oil, drawn at 325° F. for 1 hr.

Property	Average	Minimum	Maximum
	0.20% Carbon		
0.2% yield strength	120,000	105,000	135,000
Tensile strength	170,000	150,000	180,000
Elongation	12.7	10.0	15.0
Reduction of area	34.4	25.0	45.0
Brinell hardness	311	285	363
	0.30% Carbon		
0.2% yield strength	134,250	120,000	150,000
Tensile strength	190,350	170,000	220,000
Elongation	11.1	9.0	13.0
Reduction of area	30.9	24.0	37.0
Brinell hardness	400	363	444

The diagram above gives similar information about average steels in four different carbon ranges, as determined on standard 0.505-in. tensile test bars, quenched and then drawn at various temperatures.

End-quench hardenability curves are shown in the small diagram (page 387). These are averages for dozens of Amola heats with chemical analyses close to the mean of the specification. Chrysler Corp. has prepared and published about 60 loose-leaf charts showing hardness traverses of these carbon-molybdenum steels,

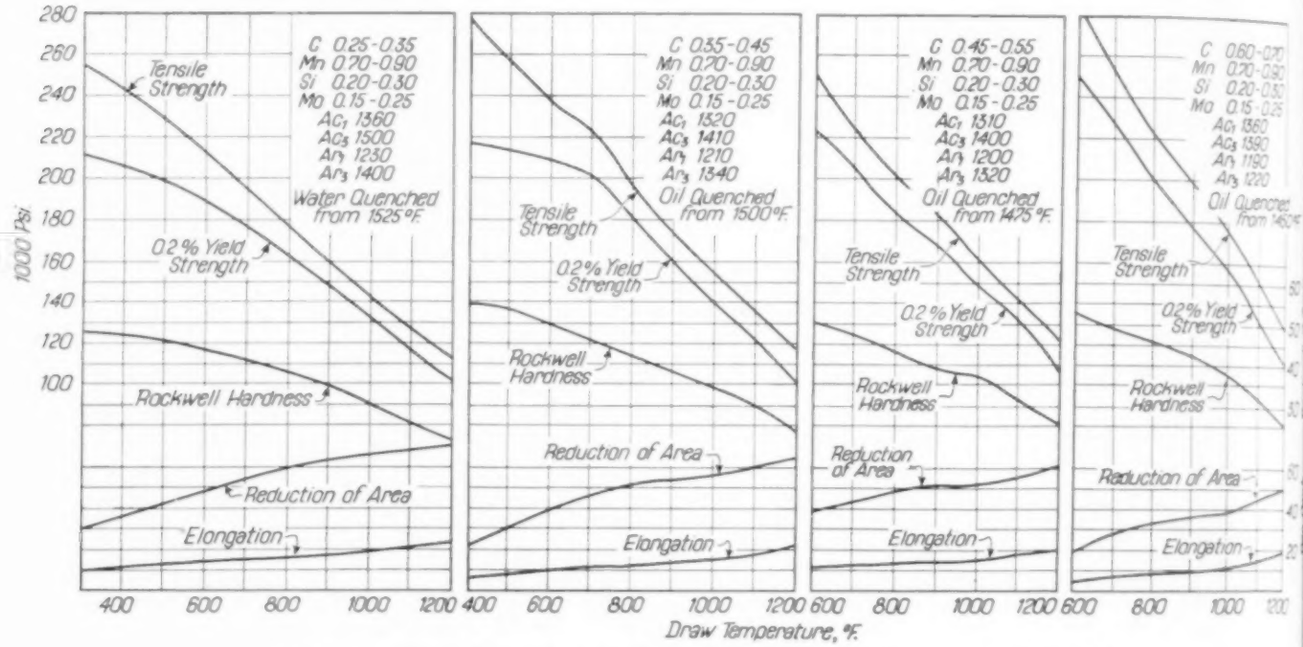


Fig. 8 — Average Physicals of Carbon-Molybdenum Steels With 0.30, 0.40, 0.50 and 0.65 Carbon, Respectively. Samples normalized at 1600° F., and heat treated in 0.530-in. rounds, tested in 0.505-in. bars. All air cooled from the draw

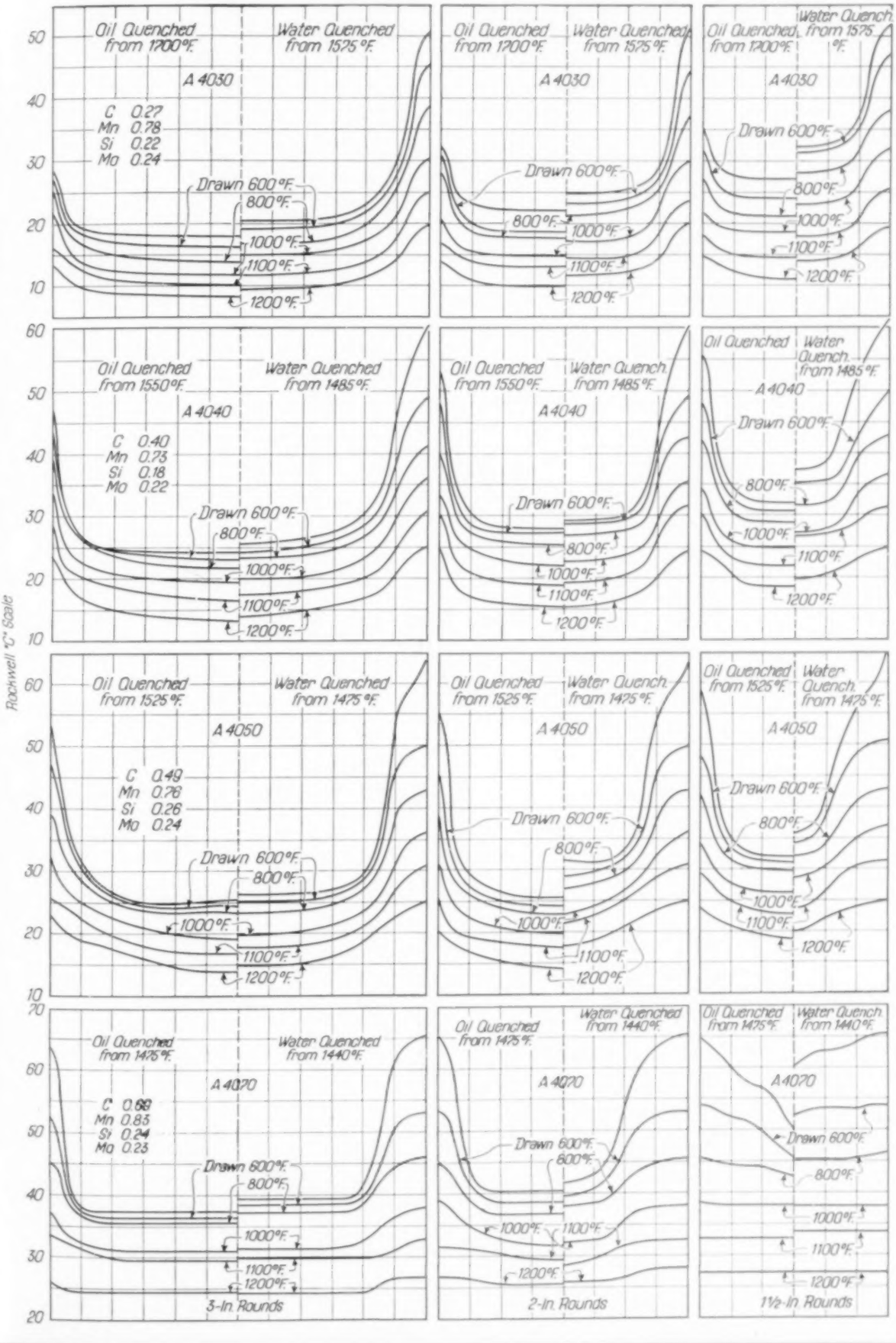
fully quenched in oil or water in various sized bars from 1 to 3 in. diameter, and tempered to probable drawing temperatures. Representatives are shown in the Data Sheet, page 389. The big advantage of complete hardness surveys of this sort is that they give an abundance of specific information that ties up with tensile property charts, made popular by S.A.E. publications, four representatives of which are also shown above.

Impact Tests

There is much discussion of the value of impact testing on small test pieces which are thorough hardening, when the material is to be used in larger sections which are not thorough hardening. It is believed by the writer that impact pieces should be tested, if practical, that represent the section to be used.

Hardness Traverses of Amola Steels

Slightly oversize round bars from representative heats were formed to dimension, fully quenched in oil or water, broken in two, smoothed, and hardness surveyed from surface to center. Similar pieces were tested after drawing variously as shown. Copyright, Chrysler Corp.



IT'LL TAKE PLENTY OF *Scrap*

TO WIN THIS FIGHT!

3 Million Tons of iron and steel scrap are wanted every month . . . Are you doing your part to help America win her battle of production?

CONSERVATION AUTHORITIES RECOMMEND THESE 8 STEPS TO GET IN THE SCRAP

1 Put some one individual in charge of scrap in all departments of your business and GIVE HIM AUTHORITY TO ACT.

2 Comb the plant and yards for dormant scrap, abandoned equipment, old boilers, pipe, moulds, obsolete dies and parts, material now being destroyed which has salvage value.

3 Survey all plant equipment, particularly idle standby or discarded machines, with a view to applying or converting them to useful production.

4 SEGREGATION:
Identify, classify and segregate scrap and supervise its handling to avoid contamination. This will increase its value.

Provide separate containers, clearly marked, for each class of scrap material.

Repair or rework worn or broken cutting tools Keep unusable small pieces and turnings segregated. Even high speed steel grinding dust is valuable.

Dismantle discarded equipment promptly into its components—electrical, fastenings, lumber, etc.—so that these parts may be utilized or scrapped.

Sort blanks, short ends, cut-downs, clippings, etc., for possible reuse for smaller parts made in the same or other departments.

Recover and reclaim used cutting oils, lubricants, surplus paints and spray finishes.

Sort sweepings and miscellaneous waste to recover scrap values.

5 Constant reminders in the form of posters, illustrations of right and wrong methods, pay envelope enclosures, house organ publicity, etc., are potent aids to the conservation program.

6 Release for scrap, obsolete engravings, electrotypes, and standing types for catalogs, forms and advertising material.

7 Inspect all refuse to detect avoidable waste and excessive rejections. Educate production executives to correct such conditions at the source.

8 For information and assistance on special phases of conservation and salvage communicate with Industrial Salvage Section, Conservation Division, War Production Board, 9th Floor, Washington Gas Light Building, Washington, D. C., or with nearest regional office

The metallurgical experience of our technical staff is available to aid you in these and other technical phases of metal salvage.

KEEP SCRAP MOVING INTO WAR PRODUCTION!

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK, N. Y.

Letters From Correspondents

Quenched Austenitic 18-8 (Nitrogen Free) Changes to Ferrite at 70° F.

SCHENECTADY, N. Y.

To the Readers of METAL PROGRESS:

A steel strip that, when placed under an alnico magnet, waits about a minute and a half before it jumps toward it, can be used to demonstrate a delayed change in the steel's atomic arrangement. The experiment is striking proof that atoms of a metal can and do move into more favorable positions of the lattice at temperatures as low as room temperature.

The strip measuring about $\frac{1}{2}\times1\frac{1}{2}\times\frac{3}{32}$ in. is made up of specially melted 18-8 stainless steel. Commercial 18-8 is austenitic and hence is not ordinarily attracted by a magnet. The writer believes that this is principally because it contains a few hundredths per cent of nitrogen which acts to prevent the normal phase change from the austenitic to the ferritic lattice, the latter phase being strongly magnetic. The nitrogen is dissolved interstitially and, aided somewhat by carbon, appears to serve as a barrier to block movement of atoms into the low temperature equilibrium positions corresponding to the ferrite lattice.

If the alloy is prepared free of nitrogen and heated to above approximately 725° C. (1335° F.) it is all austenitic (non-magnetic at all temperatures). On cooling, however, the crystal structure of the alloy rearranges itself to the ferritic lattice, beginning at about 100° C. (212° F.), at a rate which is slow at first, becomes more rapid, and then again decreases, following a transformation vs. time curve typical of the austenite→ferrite changes in carbon steels.

Hence if a strip of nitrogen-free 18-8 is held at approximately 900° C. (1650° F.) for a few minutes to rapidly convert the alloy to austenite, then quenched in cold water, it is not attracted to an alnico magnet. The austenite is substantially unchanged. After about a minute and a half, however, the strip suddenly jumps to the magnet! Enough of ferrite is formed in this time to make the strip strongly magnetic. The same delayed transformation occurs if the alloy is quenched in liquid air.

In the process of converting from austenite to ferrite, the evolution of heat brought about by the phase change, as would be expected, causes the alloy to warm up slightly. The Curie point of ferritic 18-8 is so high, however (650° C. or 1200° F.), that this has no effect on the attraction to the magnet.

Nitrogen-free 18-8 can be prepared by melting electrolytic chromium, nickel, and iron in the proper proportions either in vacuum or in hydrogen and pouring the melt or allowing it to furnace cool out of contact with air.

HERBERT H. UHLIG
Research Laboratory
General Electric Co.

Deceptive Appearances in Auto-Radiographs

COLUMBUS, OHIO

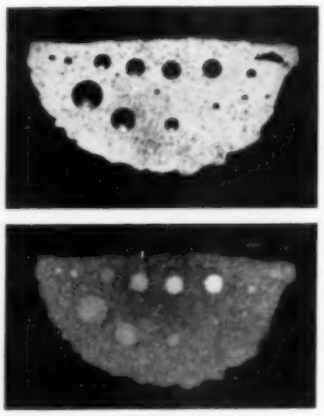
To the Readers of METAL PROGRESS:

A recent letter by W. M. SHOUPP in METAL PROGRESS for May 1942, page 688, suggested some possible applications of "radio-active tracers" in metallurgy. While the ultimate usefulness of artificially radio-active elements in metallurgical research cannot be questioned, it should be pointed out that the *interpretation* of results obtained by this or any other new and unfamiliar research tool must be handled with considerable care to avoid incorrect conclusions.

The illustration offered by Dr. SHOUPP

seems to be a good example of the pitfalls that may be encountered. The light areas in his auto-radiograph of a steel disk which contained radio-active phosphorus were interpreted to mean that phosphorus had concentrated at or near the surfaces of blow-holes or cavities in the disk. However, a simple experiment with artificial blow-holes indicates that this effect may be purely geometrical.

A flat face was cut on a piece of cast iron which contained some radio-active phosphorus as part of its normal phosphorus content. Shallow holes of various diameters and depths were drilled in this face and then a photographic plate was clamped in contact with the face for an exposure of many hours. A print of the resulting auto-radiograph is shown at the bottom of the accompanying engraving, while an ordinary photograph of the piece is shown at the top. The four holes across the top center of the piece are all about $\frac{3}{32}$ in. diameter at the surface, but the depth at the center of each hole varies from about $\frac{1}{64}$ in. for the hole on the left to about $\frac{1}{16}$ in. for the one on the right. At the extreme upper right there is a shallow, elongated, natural blow-hole, while a much smaller but somewhat deeper natural blow-hole appears at the extreme upper left. Since light regions on the print correspond to dark regions on the original plate, it is apparent that the deeper the blow-hole, whether artificial or natural, the greater the *apparent* concentration of radio-active phosphorus.



At Top Is Photograph, Actual Size, of a Flat Face of a Piece of Cast Iron With Artificial and Natural Blow-Holes. Below is a print of the auto-radiograph obtained from the same piece. Lighter areas are regions of maximum blackening caused by beta-rays from the radio-active phosphorus alloyed with the cast iron

H. R. NELSON
Battelle Memorial Institute

Solidus in the Iron-Graphite System

BERKELEY, CALIF.

To the Readers of METAL PROGRESS:

In a letter printed in the December, 1941, issue of METAL PROGRESS, I objected to the inclusion of a red solidus line labelled "Solidus in Iron-Graphite System" in the Iron, Iron Carbide Equilibrium Diagram reprinted in last October's issue. The reason for the objection was that the solidus represents the conditions under which austenite begins to melt, and, therefore, its position is determined by the reversible reaction

austenite $\rightleftharpoons$ melt

in which neither graphite nor cementite plays a part. Hence the solidus of the iron-graphite system should be identical with the solidus of the iron-cementite system.

In a reply printed in the same issue, HARRY A. SCHWARTZ defends the inclusion of the red line. He argues that it may be possible for carbon to be dissolved in austenite in two or more forms. In one form it may be combined with iron, in the other, free. The combined form he identifies with cementite, the free form with graphite. Only one of these is truly stable, the other metastable. (It may be remarked that in his interpretation the cementite form has the higher melting point and, therefore, is the stable form.)

Dr. SCHWARTZ points out that experimenters differ widely on the location of the solidus line. A number of them obtain values which cluster about the solidus attributed to cementite, while others, equally competent, find points near the graphite solidus. Details of the experiments, he believes, make it possible that one set of investigators was dealing with dissolved carbide, the other with dissociated carbide in solution. This would account for the divergent results of the experiments.

The fact that experimenters fail to agree in a region where accurate results are difficult to obtain is hardly convincing evidence for these rather complex deductions. He is not entirely convinced himself, as is shown by his cautious wording, "There is, however, at least a possibility that the dissolved carbon may be present either as the element or as the carbide."

Only thoroughly established facts belong on a reference diagram such as this. Moreover, if there actually is a metastable form of austenite, it should be indicated in many places besides the solidus. There should be two liquidus lines, since anything which affects the solidus also affects the liquidus, which deals with the same equilibrium. It would also be expected that all

the other boundaries of the austenite region would be doubled.

However, it is with the basic conception of solid solutions presented by Dr. SCHWARTZ, which is held by many scientists accustomed to thinking in thermodynamic terms, that I wish to quarrel. They have attempted to carry conceptions valuable in gases and liquid solutions over to the solid state. Thus, in a gas the unit is the molecule, a group of atoms tightly bonded together and more or less isolated from the rest of the gas. In liquids the situation is not so clear cut; nevertheless, there are groups of atoms which tend to remain together, as is convincingly shown by freezing point lowering experiments. In many cases these molecules tend to break up, in which case they are said to be dissociated. When the degree of dissociation is high, the molecule exists only in a statistical sense, and the molecular concept becomes less important; thus, it is of little use to speak of NaCl "molecules" in aqueous solution.

In solid solutions it is logical to inquire whether similar groups of atoms exist. It is frequently asked whether a compound which is dissolved in a solid solution remains as molecules or whether these molecules dissociate. In austenite, does the cementite dissolve as Fe_3C molecules (or as the diagram puts it, as carbide), or does the Fe_3C break up into iron atoms and carbon atoms so that it becomes a solid solution of carbon in iron? A number of thermodynamic investigations have been made on this topic, both for austenite and for other solid solutions. In no cases have decisive answers been obtained, due to experimental error and difficulty of interpreting the data.

However, X-ray diffraction experiments and modern theories of chemical bonding throw a new light on the matter. While molecular groupings of atoms are common in organic compounds, X-ray results show they are very rare in inorganic compounds and entirely lacking in the metallic state. With very few exceptions, inorganic compounds are like sodium chloride in that there is a continuous network of chemical bonds and no group of atoms can be singled out as constituting a "molecule". The science of crystal chemistry indicates there is no difference between chemical bonding in a compound and in an element or solid solution. Under these conditions thermodynamic treatments of solid solutions as molecular lose all value. At best the results could indicate no more than a tendency for atoms to surround themselves with neighbors of the same or a different kind.

In austenite the carbon atoms cannot be located from X-ray data due to their small scattering power. However, it is known that they fit into the interstices between the much larger, approximately spherical iron atoms. [EDITOR'S NOTE: See abstract of recent work on this problem by N. J. PETCH, in METAL PROGRESS for July, page 120.] Only one hole is near to being large enough, and the carbon atom must be squeezed to get into that. This is the reason for the small solubility of carbon in austenite. In this hole the carbon atom is surrounded by six iron atoms, which must press tightly on it. There is no room here for an Fe_3C molecule. In fact, in cementite itself there are no Fe_3C molecules! In the cementite crystal, each carbon is surrounded by six irons and each iron atom by two carbons.

Thus, to sum up, the presence of the red solidus line is objectionable on the following grounds: *(a)* There is no direct experimental evidence of the existence of a metastable form of austenite, and speculative hypotheses should not be included on a standard reference diagram; *(b)* if there were two forms of austenite, the liquidus should be double as well as the solidus, and all the other boundaries of the austenite region should be doubled; *(c)* the data of crystal chemistry render the existence of molecular carbides or any metastable forms of austenite highly improbable.

RALPH HULTGREN
Asst. Prof. of Physical Metallurgy
University of California

Temperature Conversion

INDIANAPOLIS, IND.

To the Readers of METAL PROGRESS:

Conversion of Fahrenheit into Centigrade temperatures and vice versa is probably the oftenest performed by American readers, because technologists insist on using Fahrenheit and researchers insist on using Centigrade. Conversion tables and charts are numerous; the one on page 421 of last October's METAL PROGRESS is very good.

The formulas

$$T_C = \frac{5}{9}\ (T_F - 32)$$

$$\text{and } T_F = \frac{9}{5}\ T_C + 32$$

are accurate, but generally require pencil and

paper. A simple scheme of doing it as a sequence of operations may be new to many readers of this magazine:

To Convert Centigrade to Fahrenheit:

1. Double the Centigrade reading.
2. Decrease product (numerically) by one-tenth.
3. Add 32 to remainder.

While the above instructions seem clear, several examples are shown below.

Centigrade temperature	—40	0	100
Doubled	—80	0	200
Decreased by one-tenth	—72	0	180
32 added (Fahrenheit temp.)	—40	32	212

Note that the results are exact; no approximations of any kind are involved.

To Convert Fahrenheit to Centigrade:

1. Lower Fahrenheit reading by 32.
2. Halve.
3. Increase remainder by one-tenth.

The three former examples will be given to see how it acts in reverse.

Fahrenheit temperature	—40	32	212
32 subtracted	—72	0	180
Halved	—36	0	90
Increased by one-tenth	—39.6	0	99

Note that two of the results are approximate. In fact the scheme is accurate to within 0.0111....Therefore,

4. Adding 1% (numerically) to the above will give the Centigrade temperature accurate to within 0.1%. Adding a further 0.1% to it will result in an accuracy of 0.01%, and so on.

For example, adding 1% to —39.6 gives 39.996 (the true figure is —40), and adding 1% to 99 gives 99.99 (the true figure is 100).

In many cases, however, the conversion may be performed with sufficient accuracy by neglecting the 32° correction and merely doubling (or halving) the Centigrade (or Fahrenheit) temperatures respectively, and deducting (or adding) 10%. For the range of heat treating temperatures such simple procedure results in a maximum error of 32° F. Where greater accuracy is not required, such simple conversion is highly recommended.

LEONARD TULAUSKAS
Senior Research Engineer
P. R. Mallory & Co., Inc.

Fast Sorting of Mixed Pieces
by their magnetic characteristics

HAMILTON, ONTARIO

To the Readers of METAL PROGRESS:

On reading C. S. WILLIAMS' account of the equipment he had assembled for sorting mixed castings by comparing their magnetic characteristics with a known standard, I could well imagine that other readers would have been very happy to have such an instrument on certain occasions. While instances where stock is mixed or parts are improperly heat treated are infrequent in well-run plants, when they do occur they are annoying and may be very costly.

In 1937 the writer was working at Ontario Research Foundation in Toronto, carrying out tests on the wear of balls in milling operations. Some means was desirable for identifying the alloys without marking them — indeed any marks other than a pattern of deep holes would be obliterated during the wear tests.

O. W. ELLIS, head of the metallurgical department of the Foundation, suggested using comparison induction coils and an oscilloscope

1938 Model of Equipment Designed in 1937 for Identifying and Separating Grinding Balls of Various Analyses and Treatments by Comparing Their Magnetic Characteristics Against Known Samples

Commentary on a Current Problem in Conservation and Substitution, Clipped From an Advertisement of Northern Pacific Railway (Where the Diners — Especially When They Serve Mountain Trout — Are Unexampled. Adv.)

to find differences in the magnetic properties of the alloys. The interesting possibilities of the apparatus led to the construction of a simple instrument for this purpose. Several manufacturers found it useful in sorting mixed bolts and an improved model was built in 1938. In July of 1939 a description was published in the *Bulletin* of the Ontario Research Foundation.

Since leaving the Research Foundation I have been with the Steel Co. of Canada, and have experimented further and designed still another model, which has been placed on the market. Simplicity of construction and operation gives it the advantages of low price, portability and low cost-per-test.

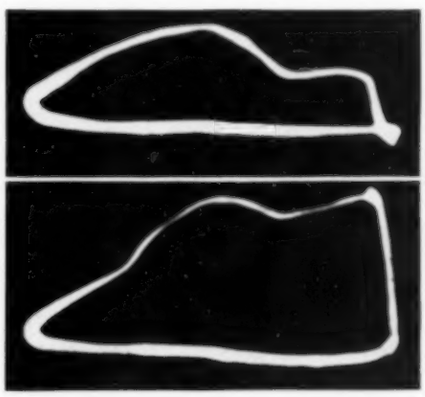
A few of the cases in which it has been used may illustrate these points:

1. 300 tons of billets were sorted in 8 hr. The instrument could be taken to the mill and plugged into the lighting circuit instead of moving the billets.

2. Several million small parts made of three grades of steel were separated successfully. Untrained girls who had never seen the machines were employed to do the sorting and they maintained a rate of 25 tests per min. or approximately 12,000 tests per 8-hr. shift. In this work the surface of the pieces was not marred in any way, even slightly as would have been the case with any type of hardness testing.

3. Some parts had been made of two grades of steel. When the mistake was discovered about half had been quenched and the rest quenched and drawn. A separation was made into the four possible groups, although the harder steel when drawn had the same Brinell hardness as the soft steel in the quenched condition.

P. E. CAVANAGH
Metallurgical Engineer
Steel Co. of Canada



Sensitivity of Equipment Indicated by Oscillograph Traces of 1010 Steel (Above) and 1020 Steel When Compared With Same Standard

Economies by Welding

UGINE, SAVOIE, FRANCE

To the Readers of METAL PROGRESS:

Following the period of waste and destruction which constitutes war comes necessarily a period of intense restrictions and severe economy. To this economy, which is imposed in all forms and on all materials, fusion welding brings a valuable advantage in the realm of metallic materials.

This economy may be exercised in various ways, as follows:

1. By prolonging the life of existing structures and apparatus.

2. By recovering or repairing useless pieces, whether defective or unserviceable.

3. By reducing the amount of metal necessary for new structures or mechanisms.

Welding presents an efficient process and new methods in these three categories:

1. Prolonging the life of metallic structures and machines implies not only repairing the breakage and damage caused by wear and corrosion (those two chief causes of slow destruction of metal, one mechanical and the other chemical), but also often provides the possibility of giving increased service and sup-

porting greater stresses — in other words, the reinforcement of old structures to make them safe for new conditions.

Thus we obtain not only the rejuvenation of a structure, but also a strengthening effect which permits greater traffic, for instance, on metal bridges — both steel bridges and the old ones of wrought iron. Wrought iron, however, presents special difficulties in welding because of its high phosphorus content (ordinarily, in Europe, on the order of 0.5%) with its strong tendency toward grain growth on heating. It is also full of elongated inclusions which give it a fibrous or laminated structure.

Along the same line is the recovery of worn parts by deposit of molten metal, which permits not only the restoration of the material to its original condition, but even an improvement in its service by judicious choice of weld metal and its heat treatment. There are innumerable applications to all sorts of parts submitted to wear and abrasion, either by machine work (tools or dies), by rubbing against solid material (rails or farm tools), by shock (crushers or drilling tools), or by exposure to corrosion and erosion by liquids (turbines) or gases (burners or motor valves).

2. The second category concerns the recovery of parts rendered useless by breakage or damage, either in use or in fabrication. Repair of castings having "foundry defects" should be particularly mentioned, because metal added by welding is deposited in the same as-cast condition as the original metal of the part. There is therefore seldom a valid reason for objecting to the repair of castings by welding (as has been done in a manner so prejudicial to French production even in critical periods) provided, of course, the repair is made according to the best practices of the art and that the repaired part be subsequently submitted to the proper heat treatments.

3. Reduction of the quantity of metal necessary for a new construction or a new piece of machinery may be effected in either or two ways, or both ways used jointly:

First, a reduction of the dimensions and the weight of the assembly, and

Second, the limitation of scarce and costly materials to those regions where their qualities and properties are utilized.

Thus a considerable reduction of weight can often be realized in contrast to riveted or cast construction. (Furthermore, this is without taking into consideration the superiority of welded over riveted construction from the standpoint of alternating stress and endurance.) In heavy structural work savings on the order of 30% of the weight of riveted construction have been obtained by better use of plates and shapes, and by the elimination of auxiliary parts and gussets. The suspicion which has fallen on welded bridges in general as a result of the collapse of the canal bridges in Belgium could not hold up under an impartial consideration and an enlightened analysis of the facts concerning these failures.

In light-weight construction the weight is reduced when compared to riveted construction because it is unnecessary to deduct the rivet holes when computing strength of members in tension, because a better fixation is secured at the ends of compression members, and because joints can generally be made without gussets.

In contrast to castings the walls of a welded part may be made of rolled material and are therefore thinner because more regular, more exact, more compact and without limitation as to thinness to that web which the foundrymen can cast. The molten zone with its risk of foundry defects is limited to the welded portion, which has less chance of physical defects than would be found in a totally cast part. Thus reductions in weight have been obtained on machine frames of 40 to 75% as compared to cast iron and of 35% as compared to cast steel.

A very interesting application of welding is the production of complex parts in which the body is an ordinary steel and the working face a special steel — for instance, a high speed steel in the case of tools. The section made of special steel can be welded onto the body of the piece or can even consist entirely of an overlay of weld metal.

Thus, all varieties of cutting, piercing and boring tools can be made up, utilizing only a minimum quantity of high speed steel, Stellite and even refractory carbides; the elements which are particularly scarce at the present time, such as tungsten, cobalt and molybdenum, can therefore be economized to the maximum.

ALBERT M. PORTEVIN
Consulting Engineer and Metallurgist

Metal Progress in High Schools

NOTRE DAME, IND.

To the Readers of METAL PROGRESS:

In the issue of *The Review* for November, 1937, a brief report was given of an experiment which had been undertaken by the Notre Dame chapter ASM. Realizing that the information which the general public possesses with regard to the nature of work and the scope of opportunities in the field of metallurgy is usually somewhat vague, and that this situation reflects adversely upon the enrollment of high school graduates in metallurgical departments of engineering colleges, this chapter entered and financed subscriptions to METAL PROGRESS for the libraries of ten senior high schools within its territory. The following sticker is placed upon the front cover of each monthly issue and, in order to do this, all copies are sent first to the chapter, then remailed:

> THE subscription to this publication has been provided by the Notre Dame chapter of the American Society for Metals, for the purpose of stimulating interest in study in the field of Metallurgy.

Shortly before the last business meeting of our chapter, a brief questionnaire was sent to each school. After reviewing the facts concerning the subscriptions three questions are asked: 1. Do you desire the subscription renewed for another year? 2. Do you use this journal in any way in class work? 3. Do your boys appear to take an interest in reading METAL PROGRESS as the monthly issues are placed in the library?

The answer to the first question is unanimously "Yes" and a few quotations from other replies received this year may be of interest to ASMembers:

"It is used as a reference in preparing required outside work."

"METAL PROGRESS is used by the students in machine shop. Eighty of the 200 students spend one hour a day in related work, and this publication contains very good related work."

"The students use it for supplementary reading in our machine shop classes.....Interest is shown when instructors make supplementary assignments from the publication. Interest is growing as the students are becoming better acquainted with the magazine."

"Used for reference material in vocational machine shop science."

"A great deal of interest is evident. Each issue shows much use before it is filed on our reference shelf."

"The boys use this work in guidance classes."

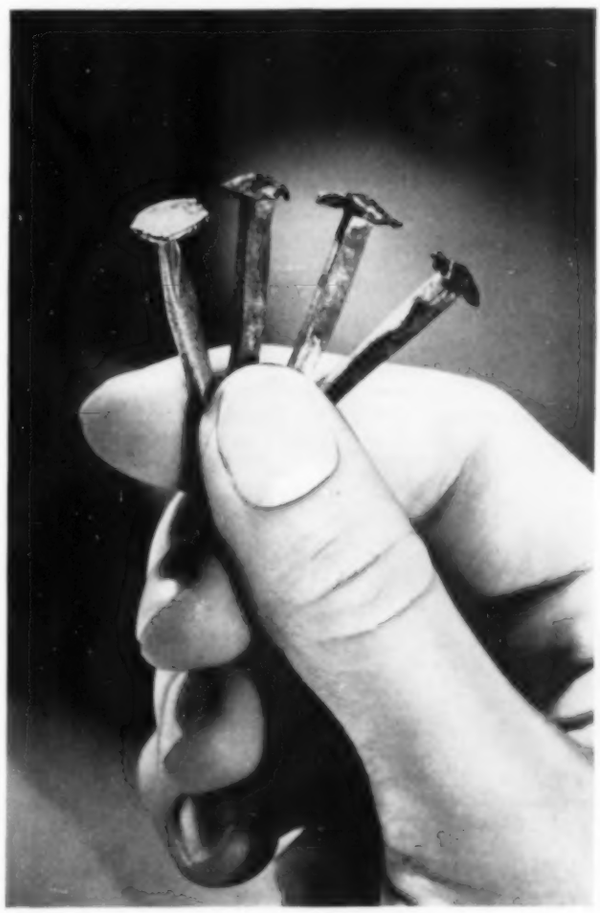
The following reply is from the librarian of the largest high school in our territory:

"I have conferred with both our instructors in Chemistry and our Shop instructor in metal work as to your offer of continuing the gift subscription. All are agreed that this periodical meets a specific need, more so now than at any previous time. The current issue is receiving more and more wear, as evidenced by the dog-eared pages, and each month the old issue is sent to the Shop for continued use by the boys there.

In the light of the experience of the past five years, the Notre Dame chapter unanimously voted to continue the subscriptions for the coming year.

ED. G. MAHIN
Professor of Metallurgy
University of Notre Dame

Three Wrought Iron Nails, Driven in Virginia in 1652 When Smith's Fort Plantation Was Built, Are Compared With a Modern Nail, Cut by Old-Time Methods, by Tremont Nail Co. of Wareham, Mass. Photo courtesy A. M. Byers Co.



Extended List of National Emergency Steels

(Aug. 17, 1942)

Designation	C	Mn	Si	Cr	Ni	Mo	Hardenability
Carbon-Manganese Steels							
NE1330†	0.28/0.33	1.60/1.90	0.20/0.35				1.71
NE1335†	0.33/0.38	1.60/1.90	0.20/0.35				1.83
NE1340†	0.38/0.43	1.60/1.90	0.20/0.35				1.96
NE1345	0.43/0.48	1.60/1.90	0.20/0.35				2.07
NE1350	0.48/0.53	1.60/1.90	0.20/0.35				2.18
Carbon-Chromium Steels							
NE52100A	0.95/1.10	0.25/0.45	0.20/0.35	0.40/0.60	0.35 max.	0.08 max.	2.38
NE52100B	0.95/1.10	0.25/0.45	0.20/0.35	0.90/1.15	0.35 max.	0.08 max.	2.98
NE52100C	0.95/1.10	0.25/0.45	0.20/0.35	1.30/1.60	0.35 max.	0.08 max.	3.22
Manganese-Molybdenum Steels							
NE8020	0.18/0.23	1.00/1.30	0.20/0.35			0.10/0.20	1.47
‡NE8022	0.20/0.25	1.00/1.30	0.20/0.35			0.10/0.20	1.56
‡NE8339	0.35/0.42	1.30/1.60	0.20/0.35			0.20/0.30	2.49
‡NE8442★	0.40/0.45	1.30/1.60	0.20/0.35			0.30/0.40	3.02
Nickel-Chromium-Molybdenum Steels							
NE8613	0.12/0.17	0.70/0.90	0.20/0.35	0.40/0.60	0.40/0.60	0.15/0.25	2.51
NE8615	0.13/0.18	0.70/0.90	0.20/0.35	0.40/0.60	0.40/0.60	0.15/0.25	2.57
NE8617	0.15/0.20	0.70/0.90	0.20/0.35	0.40/0.60	0.40/0.60	0.15/0.25	2.62
‡NE8620	0.18/0.23	0.70/0.90	0.20/0.35	0.40/0.60	0.40/0.60	0.15/0.25	2.94
‡NE8630	0.28/0.33	0.70/0.90	0.20/0.35	0.40/0.60	0.40/0.60	0.15/0.25	3.52
NE8715	0.13/0.18	0.70/0.90	0.20/0.35	0.40/0.60	0.40/0.60	0.20/0.30	2.81
NE8720	0.18/0.23	0.70/0.90	0.20/0.35	0.40/0.60	0.40/0.60	0.20/0.30	3.21
‡NE8722	0.20/0.25	0.70/0.90	0.20/0.35	0.40/0.60	0.40/0.60	0.20/0.30	3.34
NE8735	0.33/0.38	0.70/0.90	0.20/0.35	0.40/0.60	0.40/0.60	0.20/0.30	4.14
‡NE8739	0.35/0.40	0.70/0.90	0.20/0.35	0.40/0.60	0.40/0.60	0.20/0.30	4.26
‡NE8744	0.40/0.45	0.70/0.90	0.20/0.35	0.40/0.60	0.40/0.60	0.20/0.30	4.55
‡NE8749	0.45/0.50	0.70/0.90	0.20/0.35	0.40/0.60	0.40/0.60	0.20/0.30	4.80
‡NE8949★	0.45/0.50	1.00/1.30	0.20/0.35	0.40/0.60	0.40/0.60	0.30/0.40	7.50
Silicon-Manganese and Silicon-Manganese-Chromium Steels							
NE9255	0.50/0.60	0.70/0.95	1.80/2.20	—			1.83
NE9260	0.55/0.65	0.75/1.00	1.80/2.20	—			1.89
NE9262	0.55/0.65	0.75/1.00	1.80/2.20	0.20/0.40			3.21
Manganese-Silicon-Chromium-Nickel-Molybdenum Steels							
NE9415	0.13/0.18	0.80/1.10	0.40/0.60	0.20/0.40	0.20/0.40	0.08/0.15	2.22
NE9420	0.18/0.23	0.80/1.10	0.40/0.60	0.20/0.40	0.20/0.40	0.08/0.15	2.53
NE9422	0.20/0.25	0.80/1.10	0.40/0.60	0.20/0.40	0.20/0.40	0.08/0.15	2.64
NE9430	0.28/0.33	0.90/1.20	0.40/0.60	0.20/0.40	0.20/0.40	0.08/0.15	3.28
NE9435	0.33/0.38	0.90/1.20	0.40/0.60	0.20/0.40	0.20/0.40	0.08/0.15	3.53
NE9437	0.35/0.40	0.90/1.20	0.40/0.60	0.20/0.40	0.20/0.40	0.08/0.15	3.65
NE9440	0.38/0.43	0.90/1.20	0.40/0.60	0.20/0.40	0.20/0.40	0.08/0.15	3.78
NE9442	0.40/0.45	1.00/1.30	0.40/0.60	0.20/0.40	0.20/0.40	0.08/0.15	4.19
NE9445	0.43/0.48	1.00/1.30	0.40/0.60	0.20/0.40	0.20/0.40	0.08/0.15	4.54
NE9450	0.48/0.53	1.20/1.50	0.40/0.60	0.20/0.40	0.20/0.40	0.08/0.15	5.15
NE9537★	0.35/0.40	1.20/1.50	0.40/0.60	0.40/0.60	0.40/0.60	0.15/0.25	6.41
NE9540★	0.38/0.43	1.20/1.50	0.40/0.60	0.40/0.60	0.40/0.60	0.15/0.25	6.95
NE9542★	0.40/0.45	1.20/1.50	0.40/0.60	0.40/0.60	0.40/0.60	0.15/0.25	7.16
NE9550★	0.48/0.53	1.20/1.50	0.40/0.60	0.40/0.60	0.40/0.60	0.15/0.25	7.75
Manganese-Silicon-Chromium Steels							
NE9630	0.28/0.33	1.20/1.50	0.40/0.60	0.40/0.60			3.12
NE9635	0.33/0.38	1.20/1.50	0.40/0.60	0.40/0.60			3.36
NE9637	0.35/0.40	1.20/1.50	0.40/0.60	0.40/0.60			3.46
NE9640	0.38/0.43	1.20/1.50	0.40/0.60	0.40/0.60			3.58
NE9642	0.40/0.45	1.30/1.60	0.40/0.60	0.40/0.60			3.95
NE9645	0.43/0.48	1.30/1.60	0.40/0.60	0.40/0.60			4.06
NE9650	0.48/0.53	1.30/1.60	0.40/0.60	0.40/0.60			4.27

★Recommended for large sections only.

†The same as, or closely similar to, old A.I.S.I. 1942 numbers.

‡The same as, or closely similar to, steels of the same designation on first list of "National Emergency Alternate Steels" issued early in 1942.

ALONGSIDE is a list of new steel analyses, the extended list of National Emergency steels, published by courtesy of the American Iron and Steel Institute. This is to supplement the shorter list issued early this year and whose origin and intended use was described at length in METAL PROGRESS in March. The column headed "Hardenability" has been computed by the Editor following GROSSMANN's plan in the data sheet in the July issue, assuming average compositions and grain size 6; the figures represent the diameter of largest round that will harden all the way through in an ideal quench.

The steels of the NE 8000 series promulgated in January 1942 have been rapidly adopted for ordnance materiel; by July they comprised about one quarter of all the constructional alloy steel produced in the United States. Experience rapidly indicated, therefore, what steels were most adaptable and consistent. It became apparent that "tramp alloys" interfered with the uniformity of the manganese-molybdenum steels NE 8000 to NE 8500 and all but four of them have been dropped. However, the NE 8500 and 8700 steels have been doubled in number. Likewise the NE 9400 series has been established using even less chromium, nickel and molybdenum; by increasing the manganese and silicon, steels of high hardenability may be made from return alloy steel scrap using practically no new chromium, nickel or molybdenum.

Advances in Fast Surface Hardening*

By Frederic O. Hess
President, The Selas Co.
Philadelphia

ALL FLAME HARDENING (the heating of specific faces, projections or portions of high carbon steel or cast iron parts above the critical temperature by means of open burner arrangements, and subsequently quenching to develop hardness only where desired without affecting the core or body of the piece) presupposes one condition whatever the heat source may be — an unusually high rate of localized heat delivery. At the time that A. E. SHORTER and others, around 1926, made the first practical industrial applications of flame hardening, the oxy-acetylene and the oxy-gas flames were the only heat sources of sufficient speed and intensity. Ever since, the usability of flame hardening has been closely linked to the availability of oxygen supplies. Of course, surface hardening by means of high frequency electrical currents induced in the workpiece did come into the picture a few years ago — but its field of usefulness has been limited by relatively high-cost equipment and the difficulty of treating large or intricate shapes.

Within the past two years, however, means have been found to concentrate heat from the combustion of pre-mixed gas and air, as well as to accelerate rates of heat transfer to the work from gas-air burners in open arrangement. As a result, localized heat treatment, burning commercial gases carbureted with air in widely-used combustion control machinery, is now practicable.

"Superheated" and "Radiant" Combustion

At the root of almost every recent success with gas-air flame hardening lies one of two new methods of intensifying or concentrating combustion. Simplified cross-sections and photographs are shown overleaf. Precision refractory surfaces are provided in both, in contact with which burn numerous jets of completely pre-mixed gas and air. This develops a uniform incandescence over the surface of ceramic walls, and creates a radiant energy source of significant area.

The distinction between the two methods of combustion lies in the manner of utilizing the radiant heat thus developed. In the burner shown in Fig. 1*a*, known as the "superheat" type, the two radiant walls face each other, are quite close together (from ¼ to 1 in. apart in most designs), and constitute a small ceramic enclosure with a constricted outlet which encases the combustion reaction. Thus, the radiant heat developed acts almost wholly to accelerate the rate of reaction within a miniature furnace chamber at white heat. This superheats the burning gases during their interaction so that the temperature of the blast from the outlet slot (which faces the work) as

*Paper for the panel discussion on heat treatment of war products, to be held at the forthcoming A.S.M. Convention and National Metal Exposition, Cleveland, Oct. 12 to 16, 1942.

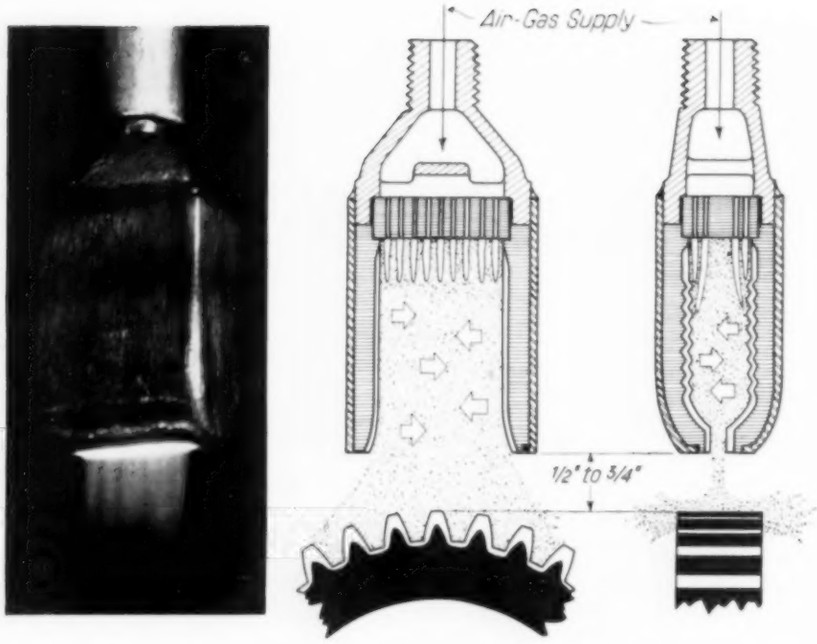
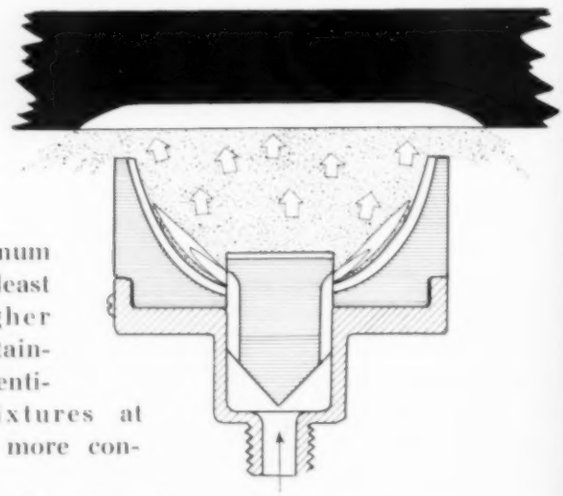


Fig. 1 — Schematic Diagrams and Photographs of Gas-Air Burners for Localized Heating of Metal Surfaces. Radiant heat is indicated by white arrows, hot combustion gases by gray tone, ceramic refractory parts by stippling, surfaces under heat by white boundaries, base metal by full black. Fig. 1a (above) is "superheat" type; Fig. 1b (below) is "radiant" type

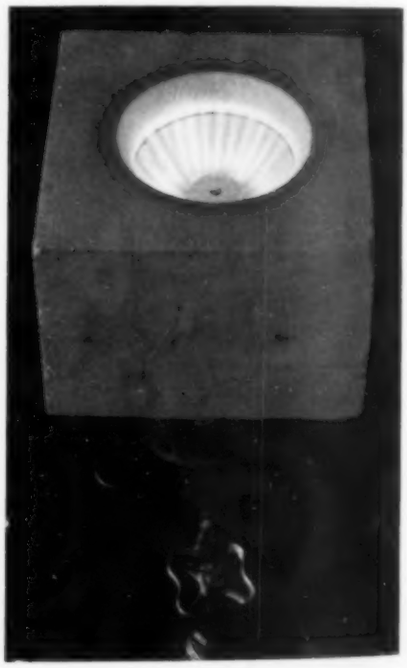


measured by a platinum thermocouple is at least 250 to 300° F. higher than otherwise attainable by burning identical fuel pre-mixtures at identical rates by more conventional methods.

In the burner diagrammed in Fig. 1*b* at right, known as the "radiant" type, the radiant energy developed at the ceramic surface impinges directly upon the workpiece and accelerates the rate of heat transfer from the burner to the part being heated. To do this the incandescent surface is arranged as a bowl-like concavity (2 to 7 in. in diameter) which faces the work at close range. This incandescent surface can be maintained at temperatures as high as 2850° F., and transfers the radiant heat very rapidly. (The rate varies directly as the difference between the fourth powers of the absolute temperatures of the radiator and the receiver, and inversely as the square of the distance between them.)

Special burners have also been designed combining various features of "superheated", "radiant", and conventional combustion. Figure 2 shows one for the continuous hardening of skate blades. Although it is essentially a superheat burner, it permits much of the radiant energy to impinge directly upon the blade edge. Another burner is an adaptation of Fig. 1*b*, essentially a radiant burner which normally does not blast or torch at all, modified by some central flame jets to project hot products of combustion along the axis of firing, so as to deliver more heat in the center of the heated disk than at its edges to compensate for heavy conductive metal masses or irregularities in surface contour.

The largest true superheat type yet constructed delivers 1,000,000 B.t.u. per hr. despite the fact that it measures only 17×13×7 in. outside (40,000,000 B.t.u. per hr. per cu.ft. of combustion space, or ten times the "maximum possible" a few years ago with then-known burners). It has 5-zone control and a narrow outlet-slot about 15 in. long shaped in refractories to conform to the shape of the piece. This burner is used for hardening alloy treads on caterpillar track shoes.



Successful performance is contingent upon the use of *(a)* an air-gas mixture at 1 to 2 psi., and *(b)* a supply which is quickly and easily controllable. Utilization of such burners near the limits of their capacity is recommended. An intimate air-gas mixture at high pressure is necessary. Most applications, furthermore, necessitate cutting-out or cutting-in of burners, which must be done without affecting the operation and adjustment of the others.

The importance of the above factors becomes apparent when one considers the difficulty of recording surface temperatures in open heat treating machinery, and thereby automatically regulating heat inputs and machine speed according to actual metal temperatures. In flame hardening, flame annealing, and other open heat treating machinery, reproducible results are insured by accuracy in burner design, precision in maintaining gas-air ratios and pressures, close regulation of time of exposure to heat, spacings between burner and work, and control of mechanism movements.

Applications to War Production

Consider the hardening of armor-piercing shot. Open superheat burners arranged in spirals within multi-station automatic machinery have for some months been hardening armor-piercing shot on over-all heating schedules of 6 to 12 min. with fuel consumptions about 35 and 125 cu.ft. of natural gas per piece.

Recently even these figures have been cut in half by adapting miniature radiant bells which just fit a single rotating shot which may be brought uniformly to, say, 1600° F. in 3½ min., or to 2200° F. in 8 min.

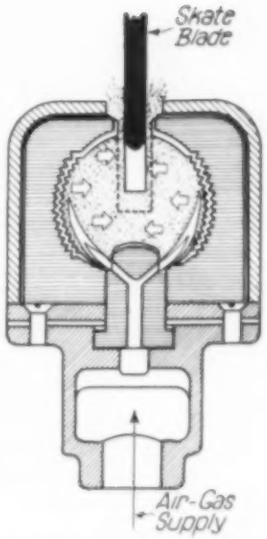
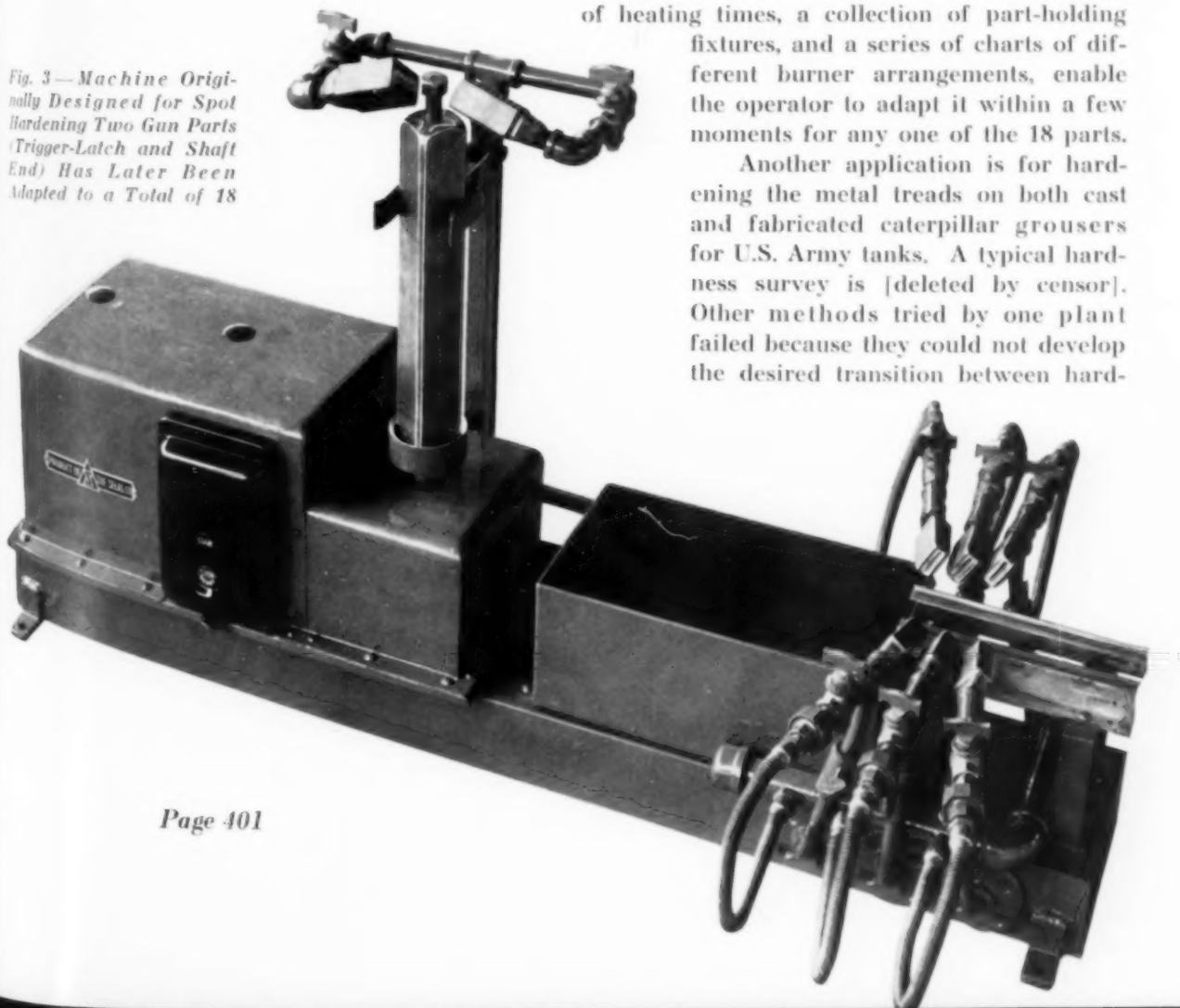


Fig. 2 — Burner for Hardening Skates

Figure 3 shows a unit for hardening anti-aircraft gun parts. It is notable because it has already been utilized for 18 different items. You see it here as originally designed for only two pieces — a trigger-latch and a star-pinion on the end of a shaft. As it is used today, each burner is mounted with a double-swivel connection so that it may be manipulated into almost any position in the manner of a dentist's drill. A simple schedule of heating times, a collection of part-holding fixtures, and a series of charts of different burner arrangements, enable the operator to adapt it within a few moments for any one of the 18 parts.

Another application is for hardening the metal treads on both cast and fabricated caterpillar grousers for U.S. Army tanks. A typical hardness survey is [deleted by censor]. Other methods tried by one plant failed because they could not develop the desired transition between hard-

Fig. 3 — Machine Originally Designed for Spot Hardening Two Gun Parts (Trigger-Latch and Shaft End) Has Later Been Adapted to a Total of 18



ened outer layer and unhardened body. Sides and faces had to be hard against wear, but the lower corners must be soft and the transition gradual, because welding had to be done at that point. The 5-zone superheat burner described above satisfactorily does the job at a pace of one piece every 90 sec. Eight such burners supplied from two combustion controllers delivering 80,000 cu.ft. per hr. of air-gas mixture constitute one production unit.

Flame Hardening Gear Teeth With Gas-Air "Superheat" Burners

Gear Type	Diameter	Face Width	Burners in Ring	Heating Cycle	Type of Gas
Pinion	1 in.	1¼ in.	4	15 sec.	Manufactured
Spur	3½ in.	1¼ in.	6	110 sec.	Mixed
Spur	4½ in.	1¼ in.	6	90 sec.	Manufactured
Ring	14 in.	½ in.	20	50 sec.	Natural
Triple-step (65 lb.)	11 in.	4 in.	24	480 sec.	Natural
Herringbone (175 lb.)	24 in.	4 in.	36	360 sec.	Natural

The sprockets which drive the tank track caterpillars are also flame hardened in automatic machinery at another plant. The sprocket is motionless in the firing station so that two burners per tooth (total 52 per 2-line machine) protrude between the teeth and harden their sides as well as their tips. Figure 4 [deleted by censor] shows the hardness contour which must be held in this job.

All three cases — a.p. shot, grouser treads, and sprockets — are significant because the mass of metal is large. This condition makes for rapid heat loss by conductivity, and this has long been a stumbling block for gas-air flame hardening.

There is insufficient time to dwell long in the broad fields of camshaft and gear hardening. In one machine 13 superheat burners in a special water-cooled block are mounted on each side of an automotive camshaft so that each of the 12 cams and the one eccentric can be hardened simultaneously. Appropriate baffles, or water cooled blocks, protect all other parts of the shaft, which rotates continually during the process. Three fully automatic machines produce at a rate of 120 shafts per hr., yet neither the shaft itself, nor the core of any cam or eccentric, nor the precisely machined helical gear in the center, is affected.

As for gear hardening, the adjoining table gives the actual production time required for various gears, 1 to 24 in. diameter, 6 to 11-pitch. In the case of the largest gear, the new equipment reclaimed $11,000 worth of gears scrapped because of distortion during furnace heating. All were salvaged by utilizing the gas-air flame hardening machine temporarily as a flame-annealer; the softened gears were then re-cut and rehardened. This gear has herringbone teeth with 4-in. face, weighing 175 lb. — the heaviest piece ever flame hardened by open automatic machinery utilizing only gas and air as fuel, prior to the time when shot and tank treads were hardened.

Summary of Advantages

First, of course, the equipment described eliminates oxygen cylinders, oxygen generating equipment, or special high-frequency electrical generators, and therefore reduces original investment, operating, and maintenance costs. Records of one thorough production test may be quoted as illustrative on 8-pitch 32-tooth gears, 4½ in. O.D., 1¼ in. face: *Oxy-acetylene flame;* 3 cu.ft. oxygen, 3 cu.ft. acetylene, 12¢ fuel cost, 26 sec. heating time. *Air pre-mixed with manufactured gas;* 5.4 cu.ft. gas, 0.0022¢ fuel cost, 90 sec. heating time. *Air pre-mixed with natural gas;* 4.8 cu.ft. gas, 0.0036¢ fuel cost, 120 sec. heating time. Figuring labor at prevailing rates, the customer (a nationally known maker of multiple drilling equipment) calculated an over-all cash saving of 65% for the air-using methods over the oxygen-using method, even without the advantage of multiple station operation of automatic equipment.

In contrast to heating in furnaces followed by liquid quenching and drawing, treatments in open machinery require less structural work, floor space and brick work. Therefore, they can generally be set up and put into production in less time and with less investment.

Users have also reported two significant metallurgical advantages: They have discovered that neither the "superheating" of the gas-air reaction nor the generation of "radiant" heat in open burner arrangements produces temperatures at any point sufficiently high to overheat sharp edges and small projections of steel parts, even during protracted exposure. This safety factor greatly reduces the skill required of flame hardeners — a point worth contemplating in this era of newly trained help and female labor. Another interesting corollary is that, in the hardening of gear teeth (say of

6-pitch) by the spinning method, speeds of rotation may be reduced (or parts even totally stopped) and the heat penetrates between teeth without danger of burning their outer edges.

Possibly the most characteristic difference lies in the transition zone of metallurgical structure from hardened surface to soft core. [Two figures and descriptions deleted by censor.] In two comparable parts hardened by induction heating and by gas-air methods, hardness at surface is according to specification in each case; the difference lies in the rate of transition from hardened case to soft core. In the induction-hardened piece the Rockwell drops 20 points within ½ in. On the other hand, in the gas-air hardened item, no two adjacent ½-in. square areas differ by more than 3 or 4 points.

One of the biggest possibilities lies in the developing of physical and metallurgical characteristics according to a predetermined pattern. Conventional practice in furnace work has been to heat for a time calculated for the heaviest section, and keep pieces in furnaces long enough to heat the heavy section while the light section soaks. Here the metallurgist may be on the horns of a dilemma. He may have to give the heavy portion enough time at high heat to dissolve carbides, yet the thinner portions are there enough longer to cause excessive grain growth. Changes in conventional practice might also show remarkably beneficial heat treating results — and such changes are now within the realm of possibility — if time as well as the temperature is brought under control. As an example of such a selective heat treatment pattern consider Fig. 7 [deleted by censor]. To obtain the hardness pattern shown it is necessary to graduate the heat application so the body of the part comes up to temperature at the same rate as the corners and edges, and, correspondingly, the body is cooled, during quench, at the same rate — even though it stores considerably more heat.

Looking Ahead

We are all, now, deeply absorbed in war production, and that fact gives us the right to look ahead. Heat treatments, especially production practices, are undergoing a change. We are not quite so presumptive as one observer who foresees the "total dispersion of the heat treatment department throughout the plant of tomorrow". But both the author's firm and the American Gas Association's Metal Treating and Melting Committee are convinced that more treatment than we now realize will be executed in the future, not in the traditional furnace department, but more accurately and speedily through "machine tools for heat treatment" which are designed and positioned to suit the other production machinery of the plant.

To support this prediction, one last but "substantial" example may be quoted — the demonstrated fact that, by selection, one square foot in the center of a 6-ft. square of 16-in. armor plate can be heat treated by open gas-air methods several inches deep without burning the surface, without affecting the rest of the 9-ton plate, and in record time. This fact alone foreshadows a new, fast developing, heat treating technique — or, possibly, "technology".

Armor Steel Hulls and Bogie-Wheel Assemblies of U. S. M-4 Tanks in Production Line. Photo by Office for Emergency Management, U. S. Government

Fusion Welding of Magnesium*

By Thomas E. Piper
Process Engineer
Northrop Aircraft, Inc., Hawthorne, Cal.

OF OBVIOUS IMPORTANCE is a reliable method of welding magnesium. Even as our present capacity to produce the metal is growing, there has been great need for an acceptable process for repairing small defects in the multitude of aircraft landing wheels, engine parts and accessories. When our expanded magnesium industry gets into operation (deriving the metal from the literally inexhaustible sources of sea water and salt brines) much of this lighter metal can replace aluminum in aircraft structures — *provided* a ready fabrication method, such as welding, is available. Magnesium alloys have an equally favorable strength-weight factor and a better factor of stiffness due to the larger volume of a part in compression; they probably will also be cheaper than aluminum. At any rate, a successful welding process brings the all-magnesium plane, with its many advantages, one step closer to achievement.

Having these things in view, V. H. PAVLECKA, chief of research, and RUSS MEREDITH, welding engineer of Northrop Aircraft, started on the problem two years ago, working in cooperation with a parallel study by Dow Chemical Co. We are now able to announce and give to American war industry the "Heliarc" process. Magnesium castings containing foundry defects have been repaired with this process and welds equal to or stronger than the surrounding metal have been obtained. Almost any thickness of cast metal that can be poured may be readily welded. The weld metal is much more dense than the surrounding cast metal and far less susceptible to corrosion. It appears to have better corrosion resistant properties than the parent metal in salt spray tests, appearing to be cathodic to the adjoining metal, which causes minor pitting of the original metal adjacent to the weld under severely corrosive conditions.

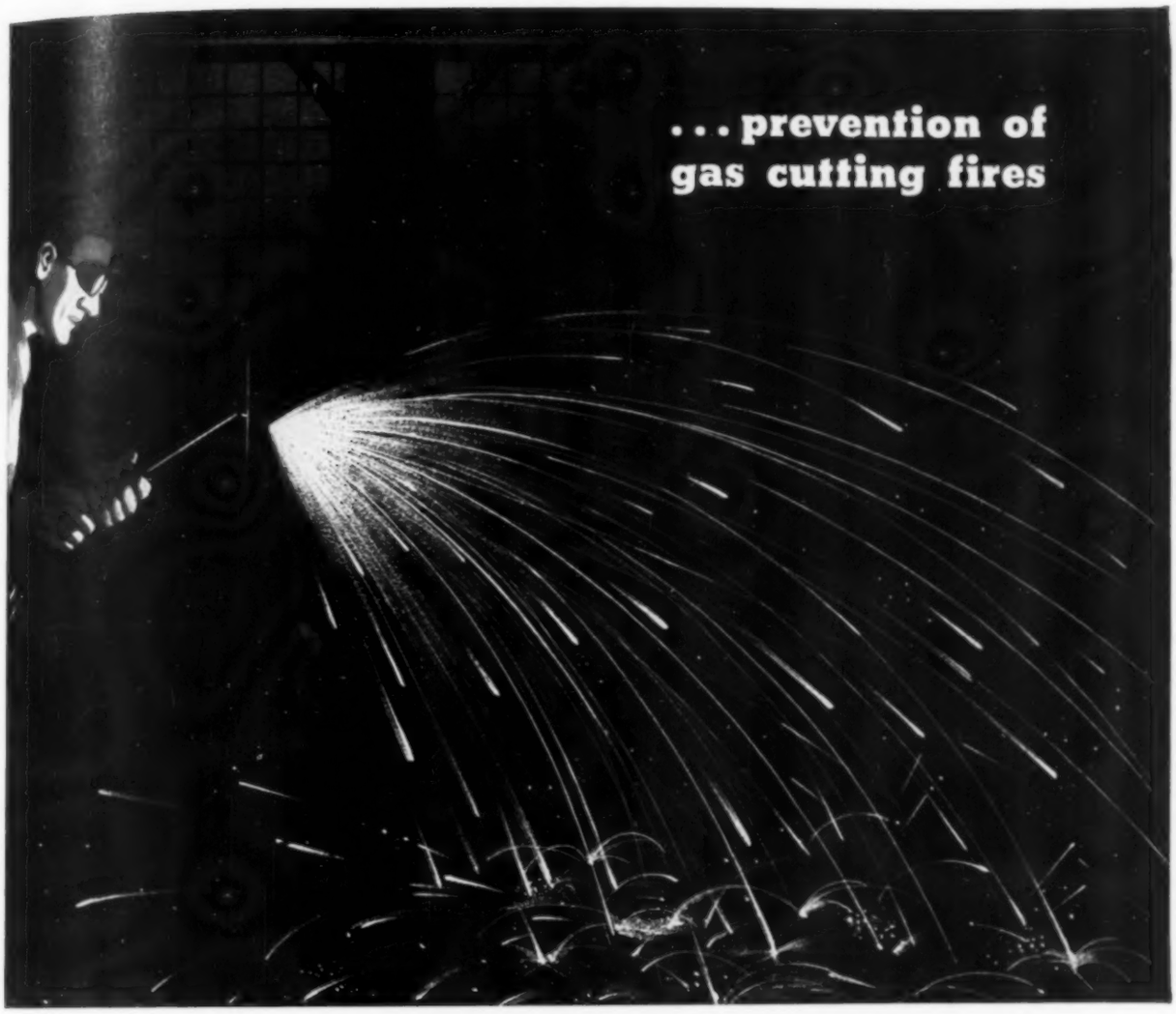
The illustration shows the "torch" and filler rod joining two extrusions with a longitudinal seam. A sheath of pure helium gas is blown out of the tip, entirely surrounding a central pencil or electrode made of tungsten, from which a direct-current arc passes to the work to generate the required body of concentrated heat. The arc is produced directly between tungsten electrode and base metal, rather than between two tungsten electrodes as is the practice in atomic hydrogen welding.

In the heliarc welding process, a shield of helium gas thus envelops the molten metal. Because helium is an inert gas, it prevents oxidation and eliminates the necessity of a flux and the danger of entrapped inclusions in the weld metal that would promote corrosion. Helium has over five times the specific heat of air and when in motion prevents the accumulation of heat in the metal around the weld, thereby keeping it cooler and giving a better fusion and penetration with less distortion and grain growth than other welding processes.

The arc is struck by a light brushing action and quickly drawn back from the metal. (A type of torch will later be available that feeds the filler rod automatically, giving more uniform results than *(Continued on page 412)*

First Model of Heliarc Torch in Operation. Welding a Longitudinal Joint in Magnesium Extrusions

*Abstract of paper before American Welding Society.



Information supplied by National Fire Protection Association

The surest way of preventing cutting and welding fires is to keep flames, sparks, molten slag and hot metal away from flammable materials. This elementary precaution is the most often ignored.

There are other precautions which, if observed, will do much to prevent cutting fires.

1. Always check fire hazards in new locations before starting work.
2. Have precautions in individual cases specified by responsible authority.
3. Move combustible material at least 30 to 40 feet away from cutting operation.
4. Sweep floors clean before lighting the torch.
5. If combustible material cannot be moved, or if sparks or slag may lodge in wooden structures, or drop through pipes or holes to floor below, use sheet metal guards, asbestos paper or curtains to localize flying sparks or slag.
6. Before cutting steel or iron be sure that it will not drop on combustible material.
7. When finished check surroundings thoroughly to make sure *all* smouldering sparks are put out.

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MOLY

Personals

F. A. Pease, past secretary, New Jersey Chapter, has opened a new laboratory in Newark, rendering a wide range of metallurgical services.

L. H. McCreery is now in charge of the metallurgical laboratory, the Amertorp Corp., St. Louis, Mo.

H. B. Myers has left Rustless Iron and Steel Corp., Baltimore, to join McConway & Torley Corp., Pittsburgh.

George A. Russell has left Creighton Mine, Ontario, Canada, to go to Wallace, Idaho as geologist for Sunshine Mining Co.

Ralph W. Fox is now assistant ordnance engineer, Artillery Design Section, Ordnance Department, Washington, D. C.

Charles F. Benner, formerly metallurgical engineer, General Electric Co., Plastics Division, has become plant metallurgist at the Peters Cartridge Division, Remington Arms Co., Inc., at Kings Mills, Ohio.

Eugene E. Everett, formerly process engineer and metallurgist, A. F. Holden Co., is now district representative, Purdue University Office of Defense Training in Engineering, Science and Management, in Muncie, Ind.

Harvey B. Hays, recently of Talon, Inc., is now employed as metallurgist by Armstrong Cork Co.

Harvey U. Geist, formerly mill metallurgist of the Halcomb Steel Division, Crucible Steel Co. of America, Syracuse, N. Y., has been made assistant to the general superintendent.

William H. Sparrow, Jr., formerly laboratory metallurgist, Sperry Gyroscope Co., Brooklyn, N. Y., is now metallurgist, York Safe & Lock Co., Special Ordnance Plant, York, Pa.

Promoted by E. I. du Pont de Nemours & Co., Inc.: **R. B. K'Burg**, from salesman, electrochemicals department, Chicago, to manager, cyanide products research and service, electrochemicals department, Niagara Falls, N. Y.

Roy W. McIntosh has been graduated from University of Wisconsin, and is now in the metallurgical department of the Belle City Malleable Iron Co., Racine, Wis.

Carlos Cowen, formerly chemist with International Harvester Co., Richmond, Ind., is now chemist with National Cash Register Co., Dayton, Ohio.

Transferred: **R. N. Gillmor** from metallographist, Schenectady Works Laboratory, General Electric Co., to engineer in charge of the Syracuse Works Laboratory.

National Emergency Alternate Steels

Designation	Chemical Composition (b)				
	C	Mn	Mo	Ni	Cr
NE8024	0.22-0.28	1.00-1.30	0.10-0.20	....	....
NE8124	0.22-0.28	1.30-1.60	0.25-0.35	....	....
NE8233	0.30-0.36	1.30-1.60	0.10-0.20	....	....
NE8245	0.42-0.49	1.30-1.60	0.10-0.20	....	....
NE8339	0.35-0.42	1.30-1.60	0.20-0.30		
NE8442	0.38-0.45	1.30-1.60			
NE8447	0.43-				
NE8547	0.43-				
NE8620	0.18-				
NE8630	0.27-				

Will the Machinability of NE Steels prove to be a Tough Problem?

THE answer will be "Yes" or "No"—depending upon the skill used in handling the change-over.

Changes may be required in tools and tooling; changes in speeds and feeds, *and in cutting fluids*. When this last factor is considered

Stuart Oil Engineering Service

is equipped and ready to help you apply the *Right Cutting Fluid* to "cranky" steels.

Stuart's Thred Kut — Heavy Duty Cutting Oil. Recommended by America's leading machine tool builders

Stuart's Solvol — Liquid Grinding Compound. For carbide tools and where an "aquamix" solution is recommended

Stuart's Codol — Liquid Grinding Compound. Meets every test for the Ideal Modern Grinding Compound

Stuart's "Super-Kool" — America's First Transparent Sulphurized Cutting and Drawing Oil

For All Cutting Fluid Problems

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in two years!

This is aluminum at a production rate that had taken an industry nearly fty years to attain—a rate that Reynolds energy and initiative achieved n two years.

This is aluminum that would never have been available today but for the resight of Reynolds Metals Co. Planes are flying, ships are going down he ways—that could not have been built but for the strong conviction that here must be more aluminum for America.

Long before industry as a whole was called into action, Reynolds enlisted n a twenty-four hour production basis. Long before the critical need for luminum was envisioned, Reynolds knew production had to be multiplied —and they mortgaged the future to do the job that had to be done.

Today, Reynolds is producing aluminum—making it efficiently in its odern, coordinated plants, from bauxite to alumina to the finished strong lloys. The only plant in the world where these operations are completed one locality.

Today, Reynolds is dedicated, with you, to winning this war with a concentrated, single-purpose devotion to producing more aluminum, and still ore.

But when tomorrow comes, Reynolds will be with you—with more aluinum at lower prices than has ever been offered peacetime America.

ut today—it's More aluminum, for War.

EYNOLDS METALS COMPANY, RICHMOND, VIRGINIA

"The record of the Reynolds Metals Company stands distinct and alone, because this company was the first to realize that enormously increased quantities of aluminum metal would be absolutely vital if victory is to be won." ...From the speech of Senator Lister Hill on the Senate floor May 18, 1942.

REYNOLDS METAL

REYNOLDS METALS COMPANY

Personals

William H. Evans has resigned as mill metallurgist at the Alan Wood Steel Co., Conshohocken, Pa., to accept a position as an industrial analyst for the Inventory & Requisitioning Branch, Division of Industry Operation, Priorities Bureau, War Production Board.

J. E. Papy has been made eastern representative for Forging & Casting Corp., Hillside, N. J.

Transferred: **A. W. Demmler**, metallurgical engineer, Vanadium Corp. of America, to the main office in New York City.

Paul Rachett has enlisted in the U. S. Army Air Forces as an aviation mechanic at Chanute Field, Ill.

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3. **Speed Treat reduced costs $51.50 per ton of steel used**
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In this "all-out" war effort Monarch Steel is co-operating 100%. We're helping to "keep 'em rolling" with Speed Treat Steel.

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MANUFACTURERS OF COLD FINISHED CARBON AND ALLOY STEEL BARS

C. R. Austin, professor of metallurgy at Pennsylvania State College, has been conferred the degree of Doctor of Scientia by the University of Wales for his outstanding work in metallurgy.

F. B. Davis, formerly with Edgar T. Ward's Sons Co., has been appointed Buffalo district manager for Copperweld Steel Co., Warren, Ohio.

John Wischhusen is now employed at Thompson Products Co., Inc., Cleveland, in development work for the metallurgical research department.

Jack M. Noy has left Foote Mineral Co., Philadelphia, to become chemical engineer in the production department, Climax Molybdenum Co., Langeloth, Pa.

Robert C. Pultz has been promoted to senior inspector and transferred to the Ashland, Ky. plant of American Rolling Mill Co. as resident inspector of naval material.

A. E. Moredock, formerly metallurgical engineer with Chase Brass and Copper Co., Waterbury, Conn., is now chief metallurgist, Kelly Springfield Engineering Co., Allegany Ordnance Plant, Cumberland, Md.

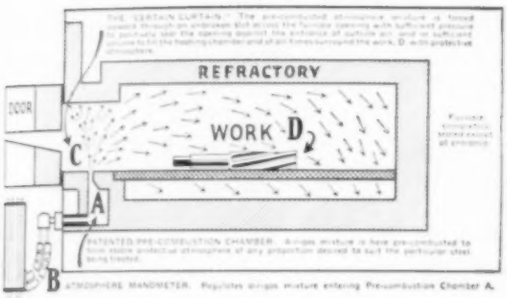
Stephen J. Parker, formerly research metallurgist, Wheeling Steel Corp., is serving as lieutenant with the Naval Reserve at the Norfolk Navy Yard, Virginia.

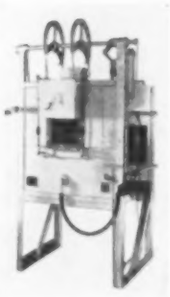
Robert B. Corbett, formerly instructor at University of Pittsburgh, is now junior metallurgist at United States Bureau of Mines, Pittsburgh.

Philipp J. Krebs, formerly of Stewart-Warner Corp., Chicago, is now heat treat superintendent with Kalamazoo Steel Process Co., Kalamazoo, Mich.

F. C. Hutchison has severed relations with The Linde Air Products Co., and is now chief engineer for Fairfax Engineering Co., Kansas City.

ATMOSPHERE CONTROL





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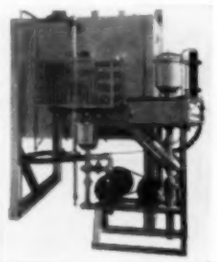
Special vertical furnace for hardening large broaches up to 7 feet.

Special furnace for hardening large dies.



Special furnace for hardening MOLY STEELS without decarburization.

Request Bulletins

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Today, 1942, when the performance of tools and dies is the vital sparkplug of war production, "Certain Curtain" furnaces are in tremendous demand by arsenals, armories, navy yards, repair ships, and every branch of industry. During fourteen years, it has become increasingly clear that "Certain Curtain" control of furnace atmosphere is something unique, outstanding, and DEFINITELY SUPERIOR in the heat-treating field. From the experience records of customers numbering in the thousands, it is established that Hayes furnace users enjoy such advantages as:

- —35% to 50% gain in heat-treating production per man per furnace.
- —SUBSTANTIALLY increased working life of tools and dies.
- —elimination of spoilage due to atmospheric attacks on the surface of the steel.

We can schedule orders for completion reasonably early, and we offer all our engineering and design resources to help you decide upon the furnaces you need.

ELECTRIC CERTAIN CURTAIN FURNACES

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E. F. BURKE, 4614 Prospect, Cleveland
J. E. FIGNER, 6388 Penn. Ave., Pittsburgh
C. A. HOOKER, 202 Forest Ave., Royal Oak, Mich.
W. G. PRAED, 4939 N. Talman Ave., Chicago

World's Leading Controlled-Atmosphere Furnace

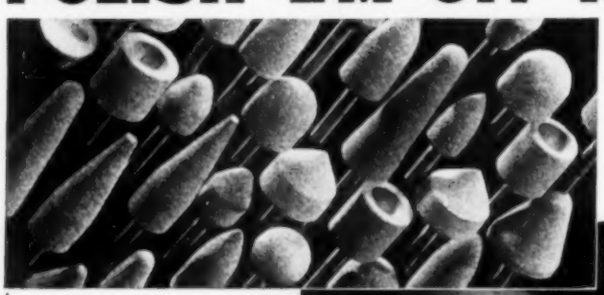
Personals

George A. Roberts has received a Doctor of Science degree from Carnegie Institute of Technology, and taken a permanent position with the Vanadium-Alloys Steel Co. in Latrobe, Pa.

Earle C. Smith, chief metallurgist, Republic Steel Corp., Cleveland, has been made a member of the American Steel Mission to Great Britain recently appointed by the Combined Production and Resources Board.

Alfred Waryas has resigned his position as assistant metallurgist at the Detroit Testing Laboratory, and is now employed as metallurgist at the Chrysler Ordnance Plant in Evansville, Ind.

POLISH 'EM OFF WITH



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Commandos of the grinding wheel industry — the first small wheels mounted on steel shanks and leading the way today with smoother, more rapid grinding, polishing and finishing of difficult jobs.

Chicago Mounted Wheels—the result of 45 years of KNOW HOW—come in a wide range of styles on different size shanks, for use with any portable or flexible shaft grinder. Several special-formula abrasives give 150% to 300% longer service. More than 200 shapes, all mounted and rarin' to go.

HI-POWER GRINDER

Here's a real production tool—a 3-pounder with enough power to drive a 2½" diameter wheel. 17,000 r.p.m. In case with accessories, $38.50.

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TEST WHEEL FREE

If you have a grinding problem, send for a Survey blank, which you'll find easy to fill out. Upon its return, our abrasive engineers will analyze it and send you without charge the trial wheel they recommend for your particular job.

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☐ Free Wheel. Size .....

Name .....

Address .....

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Chicago, Ill.

Daniel Chieger has resigned as metallurgist and heat treat supervisor for Aeronautical Products Inc. of Detroit to become plant metallurgist for the L. A. Young Spring and Wire Corp., Detroit.

John C. Barrett, formerly with Baldwin Locomotive Works, Eddystone, Pa., is now metallurgist with Taylor-Winfield Corp., Warren, Ohio.

Allan E. Martin is leaving Carnegie Institute of Technology to take a position as assistant professor of metallurgy in the School of Mines and Metallurgy, the Institute of Technology, University of Minnesota.

James A. Kavenaugh has resigned as assistant metallurgist, Naval Aircraft Factory, Philadelphia, to become welding and process engineer for the manufacturing research department of Vultee Aircraft, Inc., Detroit.

J. S. Loynd, formerly inspector in the Pittsburgh Ordnance District, is now chief inspector of ordnance at Columbia Machinery & Engineering Corp., Hamilton, Ohio.

Gerald A. Lux has resigned his position as research associate for the American Electroplaters' Society at the National Bureau of Standards to accept a position as development engineer with the Divine Brothers Co. in Utica, N. Y.

Thomas F. Scott, heat treat foreman, Trimont Mfg. Co., Boston, has been made foreman of tool and die heat treat for Wyman-Gordon Co., Worcester, Mass.

E. F. Burke, Cleveland agent for C. I. Hayes, Inc., Ecco High Frequency Corp., and Illinois Testing Laboratories, has been called to active duty in the United States Coast Guard Reserve as lieutenant, junior grade. His agency will continue in operation in Cleveland while he is absent.

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Metallurgical Laboratory
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- BELT SURFACERS
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- MAGNIFIERS
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- MICROSCOPES
- MACRO CAMERAS
- PH METERS
- POLISHERS
- POLISHING ABRASIVES
- POLISHING CLOTHS
- POWER GRINDERS
- PYROMETERS
- REFRACTOMETERS
- SPECIMEN MOUNT PRESSES
- SPECTROGRAPHS
- STEREOSCOPES
- TITRATORS

IF YOU DON'T HAVE A LABORATORY . . .

You are neglecting an opportunity to increase your production and the quality of your products. In peace time a laboratory is highly desirable — now it is essential.

There are many types of war production where laboratory control is absolutely necessary. If you are called upon to deliver a greater share of our war effort, prepare now for technical control of your plant.

During the past months we have installed many elaborate metallurgical laboratories, far more installations, however, consisted of a few machines and instruments designed to control a specific part or product. Whatever your problem may be, we offer you the advantage of our experience in similar cases.

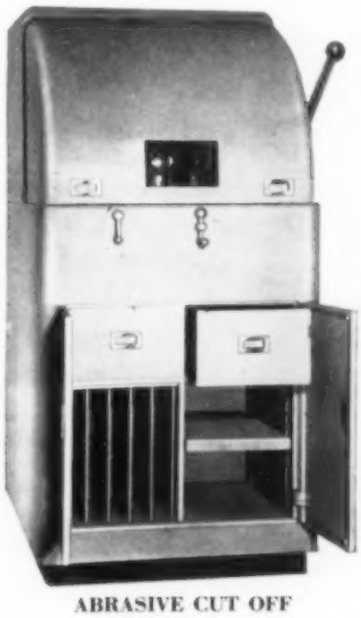
IF YOU DO HAVE A LABORATORY . . .

You have probably found that the increasing rush of production has placed a serious strain on the facilities at the disposal of your technicians. It is no doubt true that this lack of sufficient equipment results in wasted time, confusion and inaccuracy. Yet, you are called upon day after day for increased production, greater accuracy and you most likely have a research job or two that should be squeezed into the schedule.

We know of only one answer to this problem—equip your laboratory with more and better machines. Each job will then take a little less time and you will again be able to give your production department the answers they need when they need them.

SPECIMEN CUTTER ASSEMBLY No. 1140

An abrasive saw designed to cut off laboratory samples up to one inch in diameter. The recirculating water stream removes heat from the wheel and work. The cut off wheel is completely enclosed, yet readily available for changing. It is a sturdy, attractive laboratory machine.



ABRASIVE CUT OFF MACHINE No. 1000

Designed for larger work than the machine at the left. It will handle specimens up to three inches and larger. Unusual features are sturdy construction, attractive design, enclosed for safety, sensitive control, and handy storage space.

WET POWER GRINDER No. 1215

A wet grinder of unique design, built especially for metallurgical laboratories. The efficient water system is self-contained, and the cabinet design also provides for storage space. The steel backed wheels are twelve inches in diameter. Grinding is efficient, practical and safe.

Adolph I. Buehler

OPTICAL INSTRUMENTS • METALLURGICAL APPARATUS

238 NORTH LA SALLE ST. CHICAGO

Magnesium Welds

(Continued from page 404)

where the rod is fed by hand.) Best results are obtained by feeding the filler rod into the tungsten electrode, which melts off portions of the rod, thereby casting a uniform weld ingot. This procedure has been found to be superior to the practice of feeding the filler rod into the molten pool under the arc, whereby the molten pool is not sufficiently agitated to break the crust which gathers on its surface. Since the reflected heat from the tungsten overheats the filler rod, an angle of 60 to 90° must be maintained between the filler rod and the electrode. The torch must be held as near the weld as possible to obtain the most benefit from the helium shield; also the maximum arc length is 0.06 in., else poor penetration or gas holes will result.

On those alloys that have a tendency to be hot short, a rapid welding speed is recommended, approximately 3 ft. per min., to avoid cracking.

A conventional arc welding machine with direct current generator having a 150-ampere output is desirable. Separate amperage and voltage regulators must be provided and the machines should have a continuous sequence of five increments of current control.

The average life of a 200-cu.ft. helium tank is about 35 hr. of continuous welding with a medium-sized torch. Fairly pure helium gas is required; helium as purchased from the Government plant will cause no difficulties. Additional gases in helium such as carbon dioxide, hydrogen, nitrogen and the hydrocarbons may cause pronounced defects, but they can easily be removed by proper chemical absorbents. Hydrogen produces bad porosity. Oxygen films the metal, causing poor coalescence and inclusions. The presence of 7% nitrogen in the helium reduces the welding speed about one-third.

This method of arc welding has also provided an important new tool for the fabrication of structures from other alloys such as stainless steel sheet. Fusion welding of the latter becomes more and more difficult as the sheet becomes thinner and thinner, but less than 0.010-in. sheet has been very easily welded with heliarc.

In the heliarc welding of magnesium structures a tungsten electrode is used with reversed polarity making the magnesium the anode. For ferrous and copper alloys, a carbon electrode is used and the welded structure is the cathode. Craters are eliminated by reverse polarity.

From Toasters to Bombers
You would be delightfully amazed to know, were we privileged to tell, the endless war applications for "TOPHET"* and other Wilbur B. Driver Company special alloys.† Here too their dependability and performance are outstanding. Consult with us for your electrical and heat-resisting alloy requirements.
†Available in rod, wire, ribbon, and strip — both hot and cold rolled.
WILBUR B. DRIVER CO.
NEWARK, NEW JERSEY
Manufacturers of "TOPHET"* the Nickel-Chrome Resistance Wire

Heat Treatments MUST HIT THE MARK TOO!

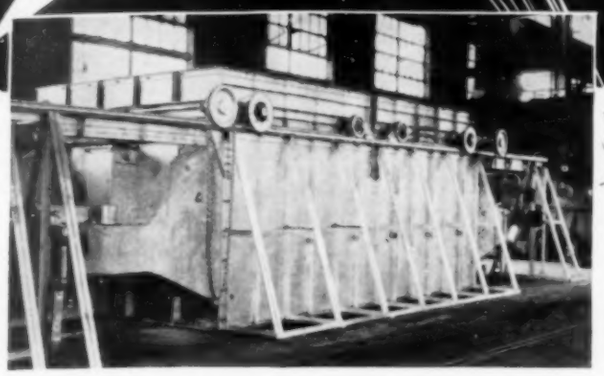
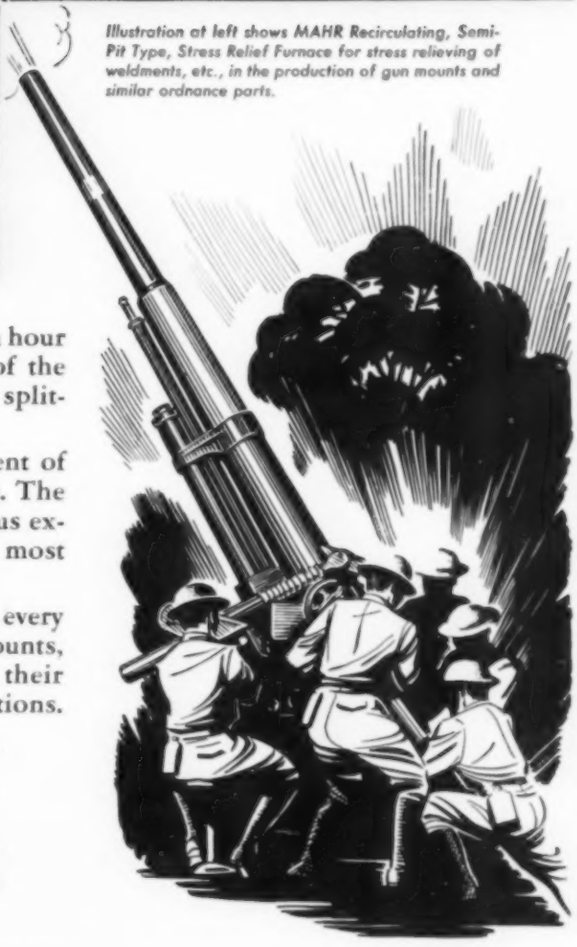


Illustration at left shows MAHR Recirculating, Semi-Pit Type, Stress Relief Furnace for stress relieving of weldments, etc., in the production of gun mounts and similar ordnance parts.



RAIDERS! Two or three miles up—flying 300 miles an hour or better! Knocking bomber or fighter planes out of the sky requires the utmost in precision manufacture and split-second aiming of the "ack-acks".

Obvious indeed is the need for accurate heat treatment of the exact type needed for gun barrels and gun mounts. The barrels must withstand the intense heat and tremendous explosive power of rapid firing. Mounts are subject to most violent strains and vibrations.

MAHR Furnaces are successfully "hitting the mark" with every type of heat treatment needed for gun barrels and mounts, planes, tanks, warships. MAHR Furnaces have *proven* their merit in thousands of wartime and peacetime applications.

A MAHR ENGINEER CAN HELP YOU on *any* heat treating problem . . . Write, wire or phone today.

MAHR MANUFACTURING CO.
DIV. DIAMOND IRON WORKS, INC.

GENERAL OFFICES—MINNEAPOLIS, MINN.
SALES OFFICES IN PRINCIPAL CITIES

A Battery of MAHR Car Type Furnaces, made in double and single end type for normalizing and annealing of gun barrels—90 mm. to 155 mm.

FOR EVERY HEAT TREATING NEED

	Furnace Types:	*Other MAHR Equipment:*
ANNEALING	CAR BOTTOM	RIVET FORGES
CARBURIZING	PIT	TORCHES
BAKING	PUSHER	BURNERS
HARDENING	ROLLER HEARTH	BLOWERS
FORGING	CONTINUOUS	VALVES
DRAWING	POT	SMITHING FORGES
STRESS RELIEF	ROTARY	

MAHR FURNACES

Throw your "SCRAP" into the fight—NOW!

Status of Strategic Metals

(Continued from page 363)

steel and forgings, toolsteel bars, pipe.

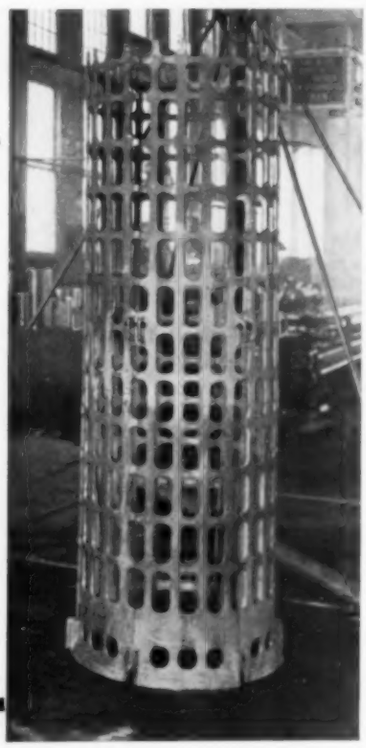
Other products in Group I, consumed by metallurgical industries, are ammonia, asbestos, benzol, diamond dies, graphite (crucible grade), and nitric acid.

GROUP II includes materials of which there are sufficient supplies for many essential needs other than for war industries. Metallurgical products in Group II are: Antimony, beryllium-copper, bismuth, calcium, calcium-silicon, columbium, ferrosilicon, ferrotitanium, iron — gray cast, malleable, and pig — mercury, platinum, ruthenium, silicomanganese, silicon and its alloys, silver, spiegeleisen, zirconium and its alloys. Other products used by the metallurgical industry in considerable tonnage include alumina abrasives, cryolite, domestic high alumina refractories (andalusite, dumortierite, kyanite, sillimanite), magnesite, natural gas, palm oil, petroleum coke, and silicon carbide abrasives.

GROUP III includes materials that are available in significant quantities as substitutes for scarcer materials, and materials that are available in large amounts unless restrictions are imposed by labor, manufacturing, or transportation difficulties. Metals included are: Ferroboron, ferromanganese, gold, indium, lead, osmium, palladium, sodium. Other plentiful materials consumed by the metallurgical industries include barium carbonate, bentonite, caustic soda, coal, charcoal, coke, chromic acid, fuel oil, gasoline, lime, lubricating oil, muriatic acid, and soda ash.

DURALOY

SPECIALISTS—
very definitely
Specialists—in
the field of
HIGH ALLOY
CASTINGS



THE word "Specialists" implies extensive experience in and greater knowledge of a given subject . . . and in this case the subject is Chrome-Iron and Chrome-Nickel Castings.

We have been making these very useful static castings since 1922 and since 1931 we've been making centrifugal castings. Both dates very definitely put us in the pioneering group.

With complete and modern casting facilities, we are in position to serve you on high alloy castings, ranging from less than a pound in weight to several tons. With a modern machine shop we can finish them to any degree desired.

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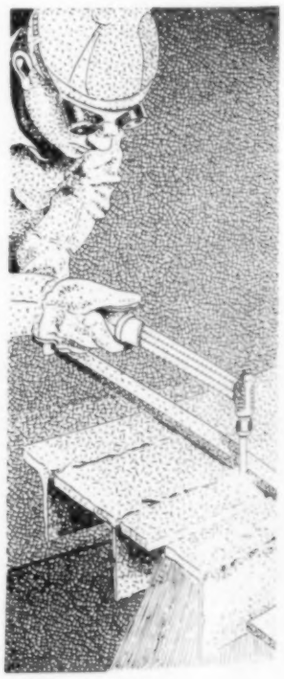
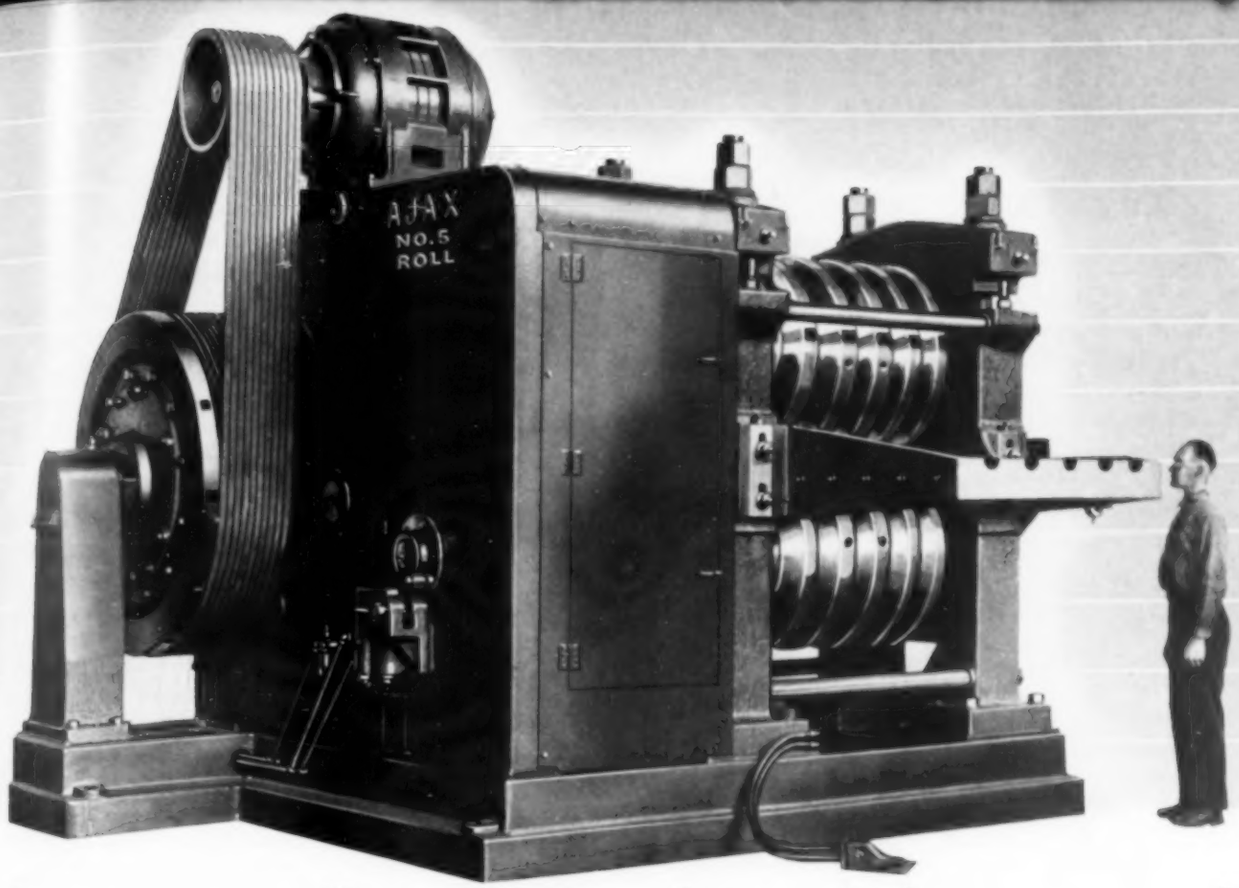




Airplane propeller blades forged faster . . . free from fiber interruptions—with

AJAX *WIDE ADJUSTMENT* FORGING ROLLS

e speed and facility with which Ajax Wide Adjustment rging Rolls draw the long tapered blanks for airplane pro-ller blades preparatory to finish forging in a hammer makes em indispensable in propeller production. The rolling eration is fast and the blanks are drawn accurately to cross-ctions which fill out the entire length of hammer die im-essions with negligible flash and a minimum number of mmer blows consistent with thorough working of the metal.

Of vital importance is the assurance that finished propellers drawn on Ajax Forging Rolls are absolutely free from transverse fiber interruptions that occur when blanks are drawn on a hammer and result in fatigue failures in flying service.

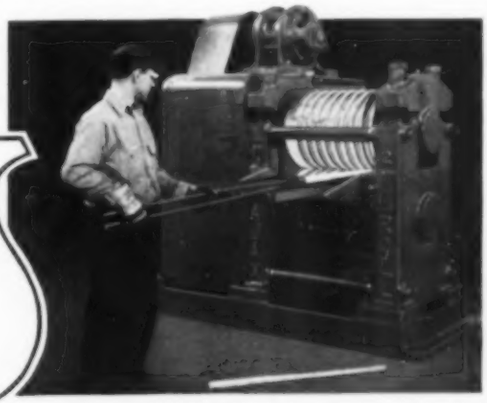
e Blank having extruded hold and blank drawn pered elliptical section to hammer forging.

Blanks of steel, aluminum, and magnesium are being drawn for a wide range of military and industrial products on Ajax Wide Adjustment Forging Rolls. Their operation is extremely simple and their production, particularly on long draws, is many times that of the fastest swagers or trip hammers.

An outstanding improvement is the wide adjustment gearing (patented). It permits adjustment between roll dies approximately 6 times that of earlier designs, thus reducing die maintenance to a fraction of former requirements. Backlash is eliminated and the smooth operation of these rolls is reflected in the regularity of the surfaces rolled.

Ajax Forging Rolls are made in five sizes covering the entire field of forging that can be handled manually. All sizes possess outstanding Ajax features that merit your purchase of Ajax Wide Adjustment Forging Rolls on the basis of mechanical soundness. Write for Bulletin 91-A.

BUY FORGINGS ON THE BASIS OF MECHANICAL SOUNDNESS



AJAX FORGING ROLLS ALSO SPEED THE PRODUCTION OF:

Gun Barrels — Machine Gun Barrels
Anti-Tank Gun Barrels
Automatic Rifle Barrels — Certain types of Bayonets

THE **AJAX** MANUFACTURING COMPANY

EUCLID BRANCH P. O. CLEVELAND, OHIO

621 MARQUETTE BUILDING • CHICAGO, ILLINOIS

Bearings

(Continued from page 369)

on available recoveries are not as large as the ones given on page 224 of August METAL PROGRESS, but since mine apply to freight cars only and imply a saving of two-thirds the weight (instead of three-quarters), the tonnages are on the same order. They approach 100 times as much as the fuse item just quoted!

There seems to be an undercurrent of belief that the copper and other strategic metal in car journal bearings can't be used in anything else but that service. I recently had a visit from a representative of one of the largest American smelting companies to whom I put this question, and he quite emphatically stated that his company could recover economically and segregate all metal in car journal bearings that was made available, in refining plants now existing.

One of the stock arguments for the solid brass bearing has always been that this brass was needed to conduct the heat away, and that any metal with a lower heat conductivity would cause the journal to run at higher temperatures. The tabulation on top of page 369 shows actual test temperature readings, read at the center of the bearing, next to the journal, out to the top of the journal box. Old standard and new composite bearings were both tested. Loads and other conditions were equal in all tests. Temperature increases were measured by embedded thermocouples after 8 hr. continuous run at each speed, and the data explode this heat conductivity theory!

It so happens that this bearing has progressed beyond the laboratory and test plant stage and is now in service under some railroad locomotive tenders. One set of bearings has run, as of the present date, some 16,000 miles and is giving a very satisfactory performance. Other test applications are being made. It differs somewhat from the iron-backed type of bearing which was tried some time in the past, so unsuccessfully that it is prohibited by the Interchange Rule 19. The substitute bearing assembly illustrated in this communication is not an integral unit, as was anticipated under this rule, but the malleable iron adapter stays with the journal box and all that is changed is the bearing itself. It is interchangeable with the present standard bearing without any other collateral fittings, and it can be and has been made in the same plants that make the conventional bearing. It requires no additional equipment or alteration in practice; the only thing required for a general extension of the bearing in use is the matter of duplication of patterns in the various foundries.

Hundreds of thousands of steel items in America's industrial war effort are being finished and protected with Phytanium-Blended Pentrate.

Approved and specified on innumerable blue prints, this durable black finish has released great quantities of strategic metals for other purposes.

The rich deep black appearance, durability, rust resistance and friction reducing qualities of Pentrate achieved immediate acclaim for steel propeller blades, aircraft control bearings, struts, rifles, side arms, machine guns, cartridge magazines, gun mounts, gauges, close assemblies and hundreds of other steel items.

Our new Pentrate catalogue will describe just how this patented, economical, low temperature process can be fitted quickly into your present war production line. WRITE FOR IT TODAY.

HEATBATH CORPORATION
SPRINGFIELD, MASSACHUSETTS

Canadian Representative, WILLIAM J. MICHAUD CO., Ltd., Montreal

The Changing Face of AMERICAN INDUSTRY

IN a few swift months, America has achieved a miracle in conversion . . . from the implements of peace to the machines of war.

Great plants transformed their production almost overnight from tractors to tanks . . . autos to jeeps . . . washing machines to gun mounts . . . table knives to bayonets . . . vacuum cleaners to fire bombs . . . airliners to flying fortresses.

In changing to these new lines, each manufacturer had to meet and master scores of problems. Wherever Cold Finished Steel is involved, B&L engineers have taken over these many problems and rendered invaluable service in specifying steels, improving machine operations and recommending special heat treating or strain tempering methods.

All for steel . . . and steel for all . . . that is today's big job. Bliss and Laughlin mills are running night and day to supply their share of Cold Finished Bars for the nation's victory needs.

Help him win by purchasing war bonds and stamps. Back him 100% by meeting your quota of 10% every pay day.

COLD FINISHED STEEL AND SHAFTING

BLISS & LAUGHLIN, INC.

HARVEY, ILL. Sales Offices In All Principal Cities BUFFALO, N. Y.

Weld Inspection

(Continued from page 367)

criticism, and that consistent failure of the production department to produce results satisfactory to him may be a reflection on his own ability as well as on factors beyond his control.

The two primary duties of the inspector are to assure himself that the spot welding equipment and operator are continually producing welding of good quality, and to assure himself that the parts contain no defective welding which might have passed unnoticed in production.

Although these two duties are sometimes divided between different inspectors, it is strongly recommended that they be combined in one man, and, furthermore, that the inspection of the finished parts or assemblies be conducted as soon after their completion as possible in order that any trend to defective welding as evidenced on the completed part may be discovered and checked at the earliest possible time.

Qualification of New Equipment — The inspector should see that every new piece of equipment is qualified for the job before it enters production. This shall be done by *(a)* the shear pull test, and *(b)* weld metal structure test, for every metal and every gage combination that the machine is intended to weld in production, and *(c)* the strength consistency test for extreme gage combinations. These three tests are performed as follows:

(a) The "*shear pull test*" determines the structural strength of the weld against loads which preponderantly fall on spot welds. It is made by overlapping the ends of two strips an amount equal to their width, welding one spot in the geometrical center of the overlap, and pulling to destruction in a tension machine. Dimensions of test strips and recommended range of average strength for 24S-T and 17S-T sheet, alclad or bare, are as follows:

Thickness (In.)	Width (Min.)	Length (Min.)	Strength (Lb.)
0.020	⅝	3	200/350
0.040	¾	4	425/775
0.060	1¼	5	775/1350
0.080	1½	5	1300/2000
0.100	2	6	1725/2450

Three tests are made and the average reported as the result of the individual deviation is less than ± 10% of the average. Larger deviations invalidate the test.

(b) The "*weld metal structure test*" involves sectioning of a joint so three consecutive spot welds are cut through their center, mounting in lucite, polishing and etching for micro-examination. The shape and size of the weld structure, the presence of holes or cracks, and the extent of the heat treated zone are then noted. Cracks extending beyond the weld metal proper may lower the fatigue strength, and cavities

(Continued on page 420)

THERE IS NO SUBSTITUTE FOR EXPERIENCE

Over 24 years of effort in the specialized field of heat- and corrosion-resistant alloy castings have given MICHIANA experience covering the widest diversity of application. To this long practical experience MICHIANA has the specialized metallurgical engineering skill, modern facilities, and trained foundrymen to insure uniformity of quality in alloy castings needed to meet the present day demands for greater production. MICHIANA alloys are doing their part in the heat treating required to develop maximum properties in materials for machine tools and war equipment, and are performing vital functions in connection with the furnaces and handling of work through these furnaces.

MICHIANA experience is at your service at all times.

MICHIANA PRODUCTS CORP.
Michigan City, Indiana

National Emergency Steels have been developed to help in meeting the needs of the steel user, while conserving strategic materials as national policy demands.

The composition of these approved steels has been worked out by leading American metallurgists, pooling their knowledge and experience for the general good.

Among the elements that impart required physical properties to NE Steels, Molybdenum has an important place.

The Molybdenum Corporation of America, producer of Molybdenum, Tungsten, and Boron, invites correspondence and will gladly furnish needful data on request.

AMERICAN Production, American Distribution, American Control—Completely Integrated.

Offices: Pittsburgh, New York, Chicago, Detroit, Los Angeles, San Francisco, Seattle.

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MOLYBDENUM CORPORATION OF AMERICA

GRANT BUILDING, PITTSBURGH, PA.

Weld Inspection

(Continued from page 418)

lower the shear strength. Since their effect is cumulative, their presence may be tolerated to the extent of 3% of the spot welds made on structural parts and 6% on non-structural. Small shrinkage cracks and porosity, whose maximum dimensions do not exceed 10% of the total thickness joined, are not considered detrimental.

(c) The *"strength consistency test"* consists of making 25 consecutive tests in a lap joint so spaced that the assembly can be sawed into 25 individual specimens of the same geometry as the single specimen used in the shear pull test. Each piece is pulled in tension, and the arithmetical average strength and the individual deviation determined. The four spot welds exhibiting the greatest percentage deviation are considered in a group by themselves irrespective of their order during welding, and the two welds giving, respectively, the greatest plus and the greatest minus deviation are considered as representative of this group. The remaining 21 welds are considered as another group and the two spot welds of this group exhibiting, respectively, the greatest plus and the greatest minus deviation are considered as representative of this group. With present operating methods it is reasonable to expect a maximum deviation of less than ± 20% for the four welds above mentioned, and less than ± 10% for the remaining 21.

Set-up Inspection — Before allowing welding of any new or different parts or any welding necessitating the use of a different welding schedule than the one on which the machine was operating, the inspector shall perform the shear pull test — *(a)*, above — and the weld penetration test — *(d)*, below — on the metal and gage combinations proposed, and the result shall indicate good quality and strength as defined by his instructions.

(d) The *"weld penetration test"* is a visual inspection of a single spot made as in the shear pull test, cross-sectioned through the weld, polished and etched. Penetration of the cast metal into the parent metal is then measured by low-power microscope. Welds that penetrate less than 20% the thickness of the sheet are indicative of an unstable operating condition; severely cracked welds may be expected if penetration approaches 80%; either of these conditions should condemn the joint or procedure, even though the welds in question appear sound. (Irregularly shaped welds having definite areas of maximum and minimum penetration shall not exceed these limits.)

Production Quality Inspection — The inspector should assure himself that the quality of production is the same as at the set-up inspection, by conducting, at least every two hours,

(Continued on page 422)

From Coast . . . To Coast

The Talk of the Machine Shops Wherever Boker's Tool Steels are used - - - - - - - "They Satisfy!"

NOVO — 18-4-1 Type High Speed Steel.

TWIN MO — 6-6-2 Tungsten Molybdenum High Speed Steel.

KINITE — High carbon, chrome, air hardening bar steel and castings.

For over 105 years we have served the industry and we are proud of it.

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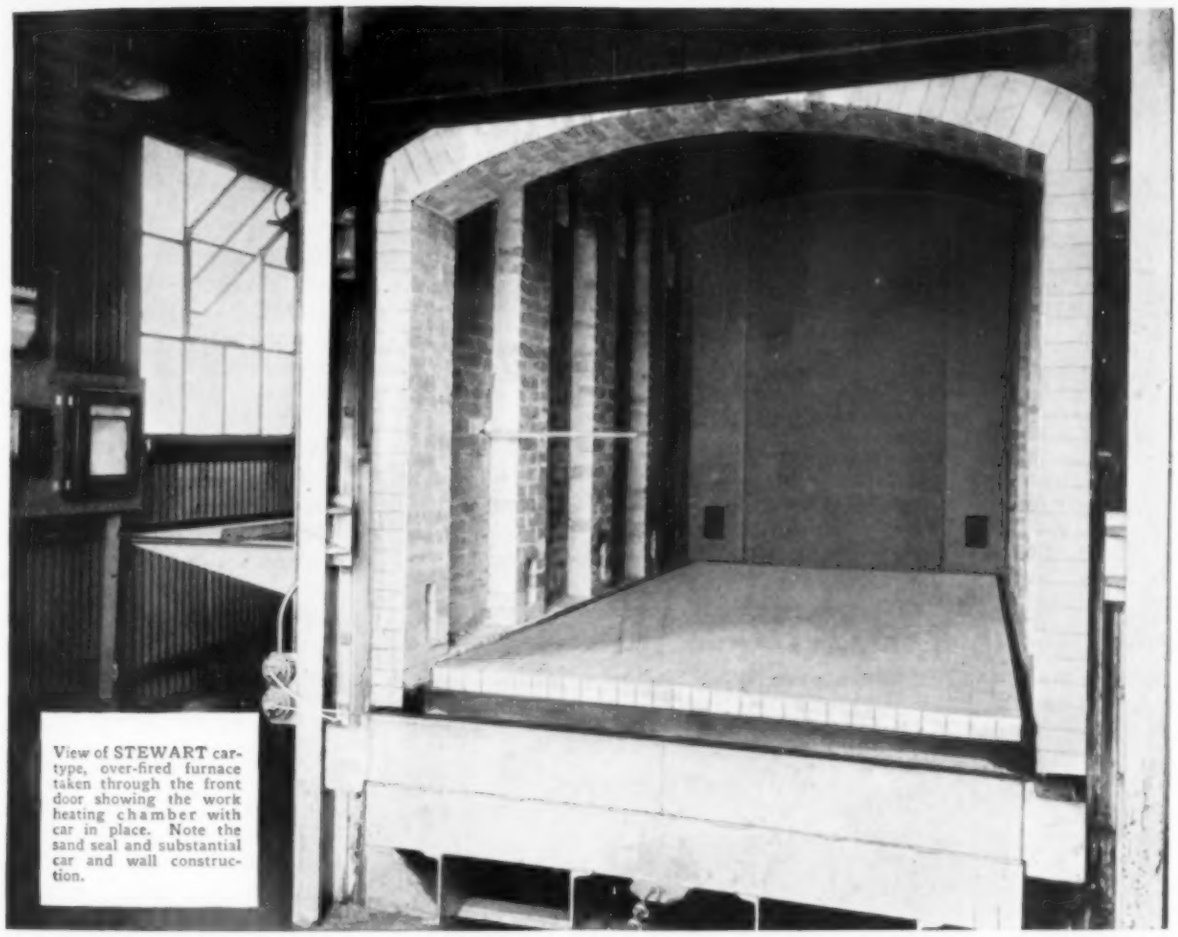
HEAT TREATING STEEL CASTINGS AND FABRICATED STRUCTURES FOR U. S. SHIPBUILDING WITH

No. 39 OF A SERIES of Typical Installations

STEWART

THE BEST INDUSTRIAL FURNACES MADE



View of STEWART car-type, over-fired furnace taken through the front door showing the work heating chamber with car in place. Note the sand seal and substantial car and wall construction.

Normalizing, annealing and stress relieving of large steel castings and fabricated structures are performed in many instances by industrial furnaces designed and built by STEWART engineers.

The STEWART car-type, over-fired furnace illustrated above is in operation in the plant of a key naval supplier. It has double-atomizing oil burners using special combustion chambers to insure complete and uniform burning of oil for maximum efficiency and temperature uniformity.

Note how the ducts from the combustion chamber enter the furnace in extra space provided above the working area, making the products of combustion travel downward through the load and out through the floor flues at car level. This assures uniform heat distribution and avoidance of flame impingement.

This installation is typical of the industrial furnaces STEWART is designing and building to meet the specified requirements of manufacturers all over the continent. In addition, STEWART builds a full line of pots and oven furnaces for which plans and patterns are now ready.

A letter, wire or 'phone call will promptly bring you information and details on STEWART Furnaces, either units for which plans are now ready or units especially designed to meet your needs. Or, if you prefer, a STEWART engineer will be glad to call and discuss your heat treating problems with you.

STEWART INDUSTRIAL FURNACE DIVISION of CHICAGO FLEXIBLE SHAFT CO.

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321 Weston Rd., So.
Toronto

FROM A 25 TON CAR-TYPE ... TO A 6 INCH POT

Weld Inspection

(Continued from page 420)

a standard shear pull test for every machine assigned to him. The deviation in the shear strength of any one specimen pulled during these tests should not be greater than ± 20% of the average of all the test specimens tested since set-up. (The set-up inspection shear pull test shall be included in the average considered.) If a greater deviation appears, the inspector shall then conduct a weld consistency check test, as described in *(e)*, below. If the results shown by this test are in accordance with the standards of good quality, the inspector should permit continuation of the operation. If not, the operation must be suspended and renewed only after proper corrections in the welding process have been made to enable it to pass the shear pull, weld penetration and weld consistency check tests.

(e) The *"weld consistency check test"* is not a substitute for nor an equivalent of the strength consistency test. It consists of laying one strip on another and making a series of 15 welds at standard spacing. The free ends are then bent apart, one held in a vise, and the other pulled so the two strips are torn apart by a stress that loads the welds in tension. The diameter of each "button" is then measured, and arithmetical average and individual deviation figured. It is reasonable to expect a deviation of less than ± 10% on weld diameters. (If the welds fail by splitting rather than pulling out, the diameter of the weld "casting" should be used.)

Additional Production Inspection should verify that the strips used in the shear pull test are the same material as is in production, and that the test pieces are characteristic of the welding done on the finished part. Early in the production run the inspector should test the part welded by means of a thin steel knife not over 0.020 in. thick inserted between the lapped parts alongside the weld in such fashion as to exert a direct tension force upon the edge of the weld, taking care that the force exerted by him should cause no appreciable plastic deformation of the metal alongside the spot weld. In all conditions the weld should be capable of sustaining such loading without fracture.

Inspection of Finished Parts — The spot welding inspector should inspect visually every spot weld on every part or assembly for which he is responsible and assure himself that their general quality is "good", as defined in the standards. In addition to this he should assure himself that the welds exhibit sufficient structural strength to withstand such loadings as may be applied to the part or assembly, by bending or twisting the part without exceeding the elastic limit of any section of the part or assembly. In case of doubt he should also test occasional welds by the pry method.

HEAT TREATING UNIFORMITY
Exceptionally close temperature uniformity for work requiring a maximum of 1300° F. is obtained in this R-S Convection Car Type Furnace. Large volume air circulation permits rapid heating and high production. Program heating and cooling is also possible on work requiring a slower rate of heating or a definite time-temperature cycle.
Automatic temperature control and combustion safety devices with dependable air circulation and proper distribution assure a continuous flow of uniformly heat-treated material.
The direct mounted electric car drive permits smooth operation with safety.
Benefit by our broad experience in the industrial heating field. Add your name to the growing list of satisfied R-S customers.
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Heat Treating
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Rotary Hearth
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Plate and Angle Heating
Soft Metal Melting
R-S
QUALITY PRODUCTS SINCE 1908
R-S Furnaces of Distinction
BUY WAR BONDS

Harry Harris, president of General Alloys Co., phoned that his advertising copy for this issue of Metal Progress had gotten mixed up with a lot of new war production contracts he had just received and could not be located!

As we had to close the forms Harry said to tell you that General Alloys is still in there fighting and would be on the front line until this fracas is over.

Adhesion of Tin-Base Bearing Metals*

By W. T. Pell-Walpole, J. C. Prytherch and B. Chalmers

IDEAL BONDING of metal to metal occurs when the two form continuous solid solutions. This cannot obtain in composite bearings for the iron or copper (bronze) shell forms compounds with the intermediate layer of tin. This discussion is confined to the casting of the bearing alloy on the pre-tinned shell. The tinned surface must either be cleared of any oxide skin which would prevent the molten bearing metal from uniting with it, or else the shell must be maintained above the melting point of tin and the molten bearing metal fed to it in such a manner that the oxide skin will float (a plan frequently adopted in die casting practice).

If the shell has been "tinned" with pure tin or with an alloy mechanically weaker than the lining alloy, then the latter must be kept liquid for sufficient time to permit complete mixing with tin on the surface and in the interstices of the compound layer; otherwise the final bond will be weak. The pouring temperature must not be high enough to permit excessive oxidation, or oxide skins may get trapped in or near the bond. In practice, the copper content of the white metal fixes the minimum pouring temperature that can be used without risk of separating Cu_6Sn_5 crystals.

After casting, the mass must be cooled without impairing the bond. This operation may be discussed in four stages:

Stage I, from pouring temperature to liquidus, is usually very short, and it is unlikely that the nature of the bond would be affected appreciably in this time. In some hand-poured bearings the molten alloy is stirred and puddled to eliminate air traps at the bond, or escaping gas.

Stage II, separation of primary crystals—The normal antimony-copper-tin bearing metals may yield either Cu_6Sn_5 "needles", the SbSn "cuboids", or both, according to composition. If more than 0.1% Ni is present, traces of Ni-Sn compound may occur. Lead and cadmium do not cause new compounds.

The SbSn cuboids segregate more easily than the Cu_6Sn_5 needles, both on account of their greater density difference and because Cu_6Sn_5 readily forms a network structure, which pre-

(Continued on page 440)

*Extracts from "An Investigation of the Factors Governing the Adhesion of Tin-Base Bearing Metals"; Paper 923, *Journal*, Institute of Metals, 1942, Vol. 68.

METALLURGICAL PRODUCTS ANALYZED SPEEDILY AND ACCURATELY

Slomin High Speed Electrolytic Analyzers

ELECTRODE design, current efficiency and improved procedures reduce deposition time formerly required by other systems as much as 25 to 40%. Under these high speed conditions hard, smooth, bright and closely grained deposits that firmly adhere to the electrodes are produced, thus assuring good reproducibility of results. Users report an accuracy of 0.01 to 0.04% for routine determinations.

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Tungsten Powder

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Ferrosilicon 75%
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Ferrosilicon 90 to 95%
Silicon Metal
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The words "Electromet", "Silcaz", and "Silvaz" and the letters "EM" and "SMZ" are trade-marks of Electro Metallurgical Company.

Adhesion of Bearings

(Continued from page 438)

vents the segregation of individual crystals. In static casting the rate of cooling during Stage II will determine the extent of segregation, and either SbSn or Cu_6Sn_5 will accumulate at the bond according to whether the shell is above or below the lining.

In centrifugal casting, even with very rapid rates of cooling, the centrifugal force causes the heavier Cu_6Sn_5 needles to move outwards toward the shell and the lighter SbSn cuboids toward the inner surface of the liquid. In hand pouring, with the axis of the shell vertical, there will be no special tendency for segregation toward the bond.

While a thick layer of brittle compounds will weaken the bond, Cu_6Sn_5 needles strengthen the bond in a steel shell, for they attach themselves, end-on, to the $FeSn_2$ in the tinned layer.

Slow cooling tends to form larger crystals and more brittle bonds. Fine crystals also nucleate the crystallization of the mother liquor (Stage III) and thus refine its grain.

Stage III, solidification of the tin-rich matrix — Since this shrinks on solidification the prime aim will be to avoid cavities. For this purpose the solidification range should be short. It varies considerably with only slight changes in composition, and with normal casting conditions the freezing range will vary with the rate of cooling. The usual antimony-copper-tin alloys (free from impurities) have a maximum matrix solidification range of 465 to 430° F.; the minimum range depends only on the antimony content. The addition of nickel does not affect this range, but lead even in small amounts will seriously extend the range, approaching the temperature of the tin-lead binary eutectic, 360° F. Cadmium similarly extends the freezing range, but less severely. The presence of lead plus cadmium has an even greater effect than either alone.

The aim is to decrease the distance the liquid metal must feed in order to reach and fill cavities as they form. Fast cooling rates mean steep temperature gradients and short distances between solid portions and liquid remainders; however, this desirable condition is opposed by the fact that fast cooling rates cause "undercooling" and so widen the normal cooling range. In die casting practice, feeding is assisted by hydraulic pressure on the feeding stream. The centrifugal process automatically provides a similar pressure. In hand pouring a suitable head of liquid metal assists feeding.

Even with an alloy of short freezing range, with optimum

(Continued on page 442)

ROTOBLAST

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for new furnace operators

WORLD WAR II has brought many changes in plant personnel. Many men without prior experience have been called on to undertake the monumental job of keeping machines and furnaces working at top speed. Perhaps some of these new men, now operating furnaces for you would like to know more about the super refractories with which these furnaces may be lined, and what precautions are necessary to secure the best possible overall performance from such materials. If your operators need this information, we invite you to call on our refractories engineers. They're men with a wide background of practical skill, gained through years of experience and an intimate knowledge of every type of furnace. They will explain what working practices will assure longest life from your super refractories and thus help you to secure continuous maximum production and highest efficiency.

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(Carborundum is a registered trade-mark of and indicates manufacture by The Carborundum Company)

Adhesion of Bearings

(Continued from page 440)

cooling rate and maintaining a pressure feed, any isolated small pool of liquid will form a shrinkage cavity on solidifying.

A multitude of minute shrinkage cavities at the bond are undoubtedly the cause of poor adhesion, especially in steel-backed bearings. Seemingly the last liquid in the interstices has drained away to feed the body of the lining, leaving shrinkage cavities at the bond. To avoid this defect, solidification must commence from the back of the shell and proceed toward the surface in such a manner that there is always a continuous supply of liquid to feed the shrinkage at the bond. The centrifugal process automatically provides satisfactory cooling conditions, since solidification starts from the shell side at either end, giving a solidus parallel to the bond in a circumferential section and inclined to the bond in a longitudinal section. In die casting or hand pouring, special provision must be made, as by maintaining the mandrel hotter than the shell with normal air cooling, or by more positive cooling from the shell side by an air blast or water spray. In hand pouring, with the cylindrical axis of the shell upright, efficient feeding should be maintained by positive cooling from the shell side and from the bottom upwards, with a head of liquid at the top which can be kept heated if necessary.

Stage IV, cooling of solid bearing to room temperature—Stresses may be set up by the differential contraction between the backing and the lining material. The coefficient of expansion for bronze is much nearer to that for tin than is the coefficient for steel, and hence the stress set up in a bronze-backed bearing will be much lower than in a steel-backed bearing.

Other factors affecting the residual stress will be the thickness of the lining relative to the shell, the rate of cooling, and the ability of the white metal to yield to the increasing stress as cooling proceeds. The extent to which the white metal can yield to the imposed stresses is determined by the rate of cooling and the creep strength of the lining. In the latter respect, the composition of the bearing metal is important, for tin-base alloys containing cadmium have much higher creep strength than other tin-base alloys, and bearings lined with such alloys have been found to crack away from the backing when cooled at a rate which could be used quite safely for similar cadmium-free linings. Clearly, cooling during the last stage should be as slow as practicable, and occur evenly throughout the bearing.

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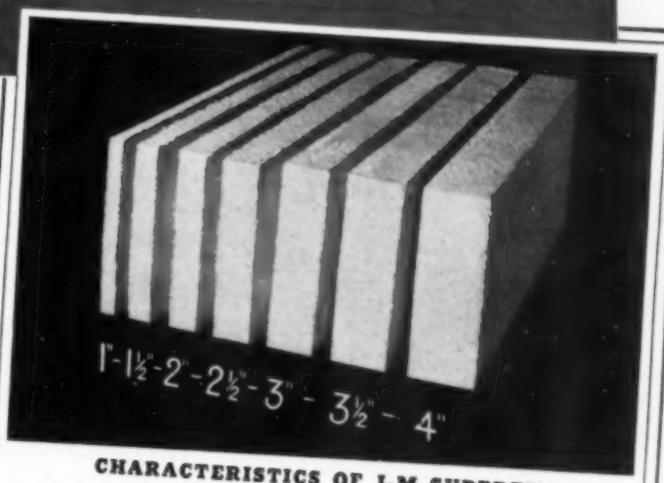
Throughout the Iron and Steel industries, J-M Superex has long been recognized as the standard block insulation for temperatures up to 1900° F. behind refractory linings.

Made of high-quality, calcined diatomaceous silica, bonded with asbestos fiber and formed into large, easily handled blocks, Superex provides both high heat resistance and exceptional insulating efficiency. For complete information, write for IN-101A. Johns-Manville, 22 East 40th Street, New York, N. Y.



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LOW THERMAL CONDUCTIVITY—the billions of tiny "dead air cells" in J-M Superex present a formidable barrier to the passage of heat . . . are largely responsible for its low thermal conductivity.

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PERMANENT EFFICIENCY—Superex maintains its high thermal efficiency indefinitely—will not disintegrate in the service for which it is recommended.

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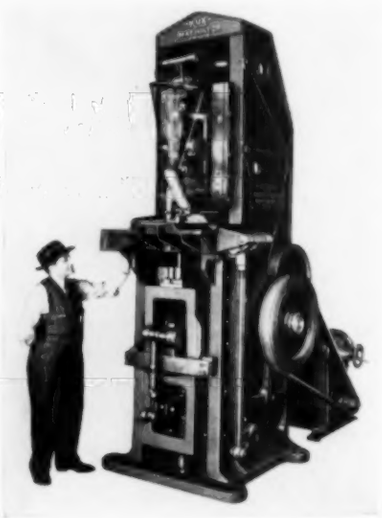
New Products Available for Metal Workers

Readers may obtain complete details on these products by writing to the manufacturer direct, or to Metal Progress, and we will gladly pass requests on to the manufacturer. Simply mention the paragraph numbers of the items in which you are interested.

Powder Metal Press

Automatic press, Model 74, is one of the largest machines of its type for producing parts from powdered metals. Oil-less bearings, iron gears and cams, metal filters, metallic electrical contact points are a few of the products that can be formed on this press from powdered iron, bronze, aluminum or platinum. Manu-



factured by Kux Machine Co., Chicago, the machine embodies new features that permit the manufacture of odd and difficult shapes, parts with cored holes, protruding lugs and various sectional thicknesses to a high degree of accuracy. (No. 81)

New Tool Stand

Designed to serve as a vise or clamp for holding micrometers, snap gages and other precision tools, which if held in the hand will expand and distort from body heat. For precise measurements, therefore, tools should be handled in a fixture of this type. Manufactured by George Scherr Co., New York City. (No. 82)

New Cutting Oil

"Cut-Aid", a new industrial cutting oil perfected by Gulf Oil Corp., Pittsburgh, is said to have greatly increased penetration, cooling power, film strength and "wetting" ability. Used alone or in combination with other cutting oils, tools bite deeper and cut faster without creating excessive heat. In one demonstration, "Cut-Aid" was used on a machine that was throwing up a plume of smoke while operating at 100 ft. per min., surface speed. After the new cutting oil was added to the lubricant already in use, there was not a trace of smoke at 300 ft. per min. (No. 83)

Radiograph Developer and Fixer

Two new additions to Kodak aids to better radiography are certain to have a wide effect on industrial X-ray processing, according to Eastman Kodak Co., Rochester, N. Y. Kodak Liquid X-ray Developer, and Kodak Liquid X-ray Fixer are tested chemicals compounded into concentrated liquids. These liquids, based on comprehensive tests and actual use with the Kodak industrial X-ray films, Types A, F, and K, are in every way the equal of those made from chemicals in powder form. (No. 84)

Abrasive Cut-Off Machine

An abrasive cut-off machine to handle any metal — hard or soft, tubular or solid, including hardened toolsteel — is being manufactured by the Challenge

Machinery Co., Grand Haven, Mich. Machine has a capacity up to 1-in. round, can be plugged into any light socket. (No. 85)

New Cr-Mo Steel

A new steel, "Elastuf Chro-Moly Modified", has been brought out to meet the W.P.B. restrictions on alloys, especially nickel, vanadium and chromium, which

(Continued on page 446)

TENSAL

ALUMINUM CASTINGS

Meeting Today's Demands
Assuring Tomorrow's Needs

★ Our battery of modern squeezer molding machines is manned by skilled workmen with years of experience in making castings. Today, they are turning out castings with speed and precision for victory. Tomorrow, this same skill, plus priceless new experience will be available for your peace-time needs.

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Makers of QUALITY SAND AND PERMANENT MOLD ALUMINUM CASTINGS

New Products

(Continued from page 444)

affect three of the standard Elastuf steels — Elastuf Type A, Elastuf Chro-Moly, and Elastuf 44. The new Chro-Moly Modified is a manganese-chromium-nickel-molybdenum steel with the permissible low alloy content. Available in heat treated and machinable condition from the tri-warehouse group of Horace T. Potts Co. of Philadelphia, Brown-Wales Co. of Boston, and Beals-McCarthy & Rogers of Buffalo. Physical data on the new steel are being compiled. (No. 86)

Welding and Brazing Fluxes

National Cylinder Gas Co., Chicago, has brought out a new line of field-tested welding fluxes for both ferrous and non-ferrous metals. Features of this new line include reduction of fumes, bubbling and boiling, and the ability to adhere to hot rods in the proper proportion with reduced tendency to blow away. (No. 87)

Welding Positioner

Heavy-duty unit has been added to line of standard welding positioners manufactured by the Industrial Division of Ransome Concrete Machinery Co., Dunellen, N. J. Machine will handle a maximum load of 22½ tons with a center of gravity 12 in. above table top, tilting it to any position through a range of 45° from horizontal in one direction to vertical in the other, for down-hand welding on almost any seam. (No. 88)

Wear Gage

Amount of material removed from metallic surfaces after wear, abrasion, grinding, honing or lapping, can be measured precisely with the McKee Wear Gage, announced by the American Instrument Co., Silver Spring, Maryland. The gage will measure as little wear as 15 millionths of an inch. The maximum is 0.0014 in. (No. 89)

Rocker-Arm Welder

Line of rocker-arm welding machines, available in 48 models, has been announced by Progressive Welder Co., Detroit. Machines are available in four capacities with three types of drive and a full range of throat depths from 12 to 36 in. (No. 90)

Gibsiloy Contacts

Gibsiloy contacts are now available in laminated metals in which materials and base metals are combined to obtain the best features of each, according to Gibson Electric Co., Pittsburgh. Gibsiloy is used as a facing where its electrical properties are used to best advantage, and inexpensive base metal is used for backing material, which results in lower costs and conservation of vital metals. (No. 91)

ELASTUF CHRO-MOLY MODIFIED ALLOY STEEL Heat Treated

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Offering to steel users the same time- and labor-saving advantages which characterize all ELASTUF Steels.

—An NE 8744 ALLOY STEEL made under grain size control, from specially selected billets, assuring dependable uniformity in quality and physical properties.

—A Heat Treated ALLOY STEEL with actual physical properties developed for each size range, thus— "Ready for use without guesswork."

—A Heat Treated ALLOY STEEL which can be readily machined, and then put into service—without further heat treatment.

Within the limitations of its tensile properties, ELASTUF CHRO-MOLY MODIFIED, Heat Treated, will replace the ELASTUF Steels—TYPE A and CHRO-MOLY—which have been retired for the duration because of the alloy shortage.

For applications requiring oil-hardening steels for heat treating after machining we have available the new NE 8744 and NE 8749 Alloy Steels Hot Rolled Annealed.

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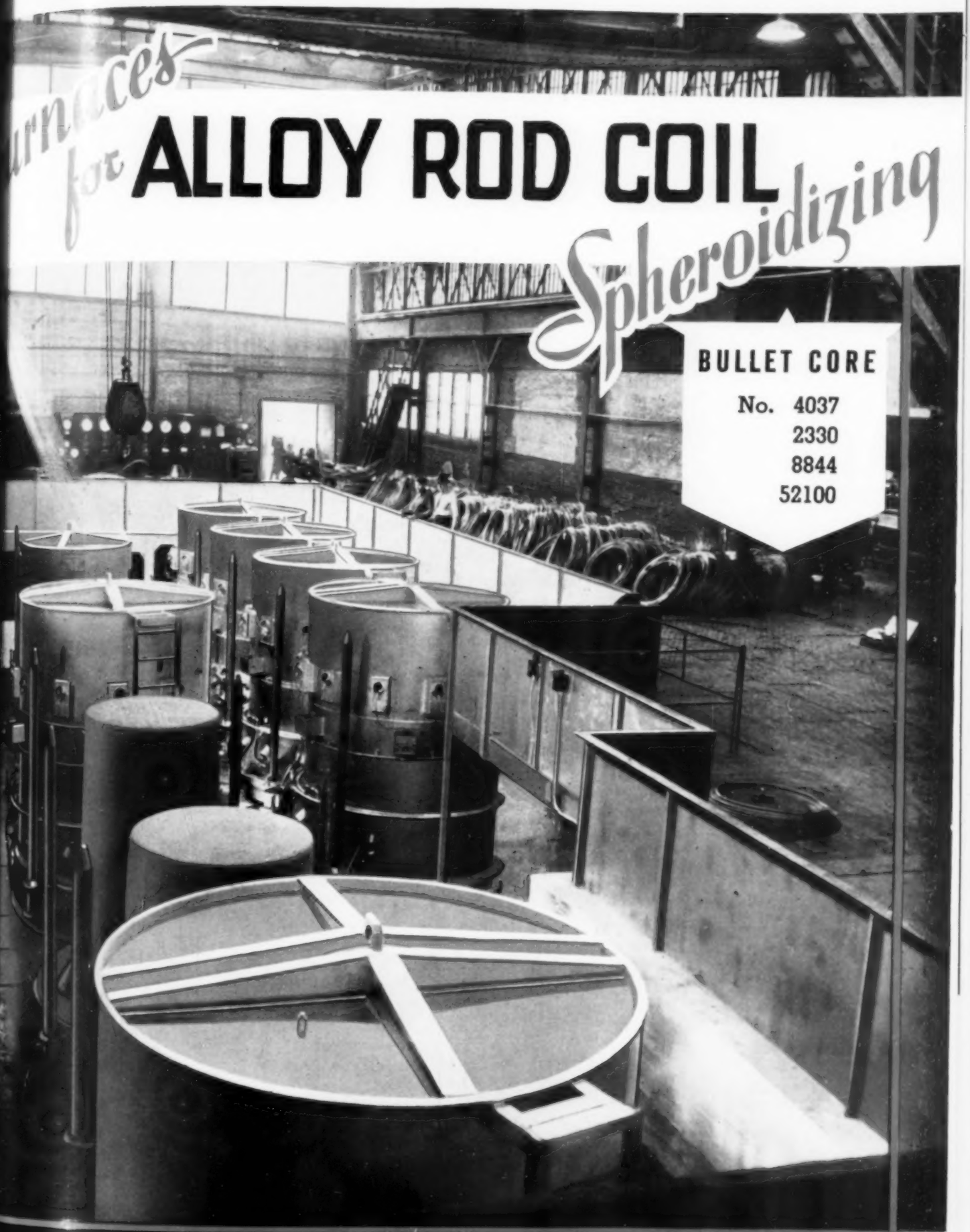


The Wilson Engineering Co.
20005 West Lake Road CLEVELAND, OHIO
Telephone AC-4670

Tool Hardening

(Continued from page 383)

expansion, which could not be accommodated by the already fully hard case without splitting. Actually it would have been far better to cool the tool right out in water, and temper it later by reheating the whole tool to the desired tempering temperature.

This type of cracking can also occur where an attempt is made to part-quench in water, and then remove and finish-quench in oil. *It is usually far safer to boldly quench right out in water,* if the material is a water-quenching steel.

The Tempering Operation

Tempering is the milder reheating that follows a complete quench. Note the word "complete". More tools are cracked and ruined by failing to remember that word than from any other cause. It is an excellent rule for all varieties of toolsteels, no matter what the quench, to cool them to the point where they can be handled comfortably *with the bare hand* before placing them in the tempering furnace. The hardener's hand is the best possible thermometer. This will insure that all of the hardening reactions have occurred that can occur throughout the entire mass of the tool (unless the piece is refrigerated in liquid air). In the plain carbon steels this means practical completion of the hardening transformation, and the work of the tempering furnace is then the same as the stress relieving furnace on a welded structure, or the process annealing on a cartridge case—it merely relieves existing high internal stress and thereby toughens the piece.

Alloy steels do not completely transform during rapid quench; a certain proportion of the solid solution (the structure known as "austenite") formed during the heating above the critical temperature, is retained in the quenched tool. This is really an unstable microstructure, for it would tend to harden (change to an intimate mixture of iron and carbide particles) when it gets a chance. If tempering is at high enough temperature and for long enough time, this remnant also transforms and the structure is fully hardened; a notable gain in hardness is thereupon experienced—an action called "secondary hardening". It is most pronounced in high speed steel. For example, the hardness of a properly quenched tool immediately after cooling may be Rockwell C-66, but this drops to C-62 on tempering (stress relieving) at 900° F. Tempered at 1050° F., however, the secondary hardening action brings the value up above C-64.

Just as a task force is sent out to accomplish a definite war operation, so is Ampco Metal selected to do a definite application job.

Where parts are subject to highly stressed conditions — where a bronze is needed that can "take it" under severe operation — where good bearing characteristics and long life are imperative — Ampco Metal does full duty and fulfills its task.

Physical properties of Ampco Metal are highlighted in the table below. To meet certain government specifications, modifications of standard grades are available to conform to specific chemical requirements . . . . These Victory Grades are subject to the standard Ampco laboratory control that extends from raw material through to the finished product.

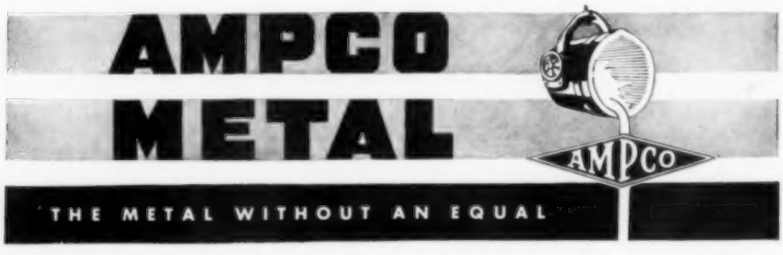
PHYSICAL PROPERTIES OF AMPCO METAL

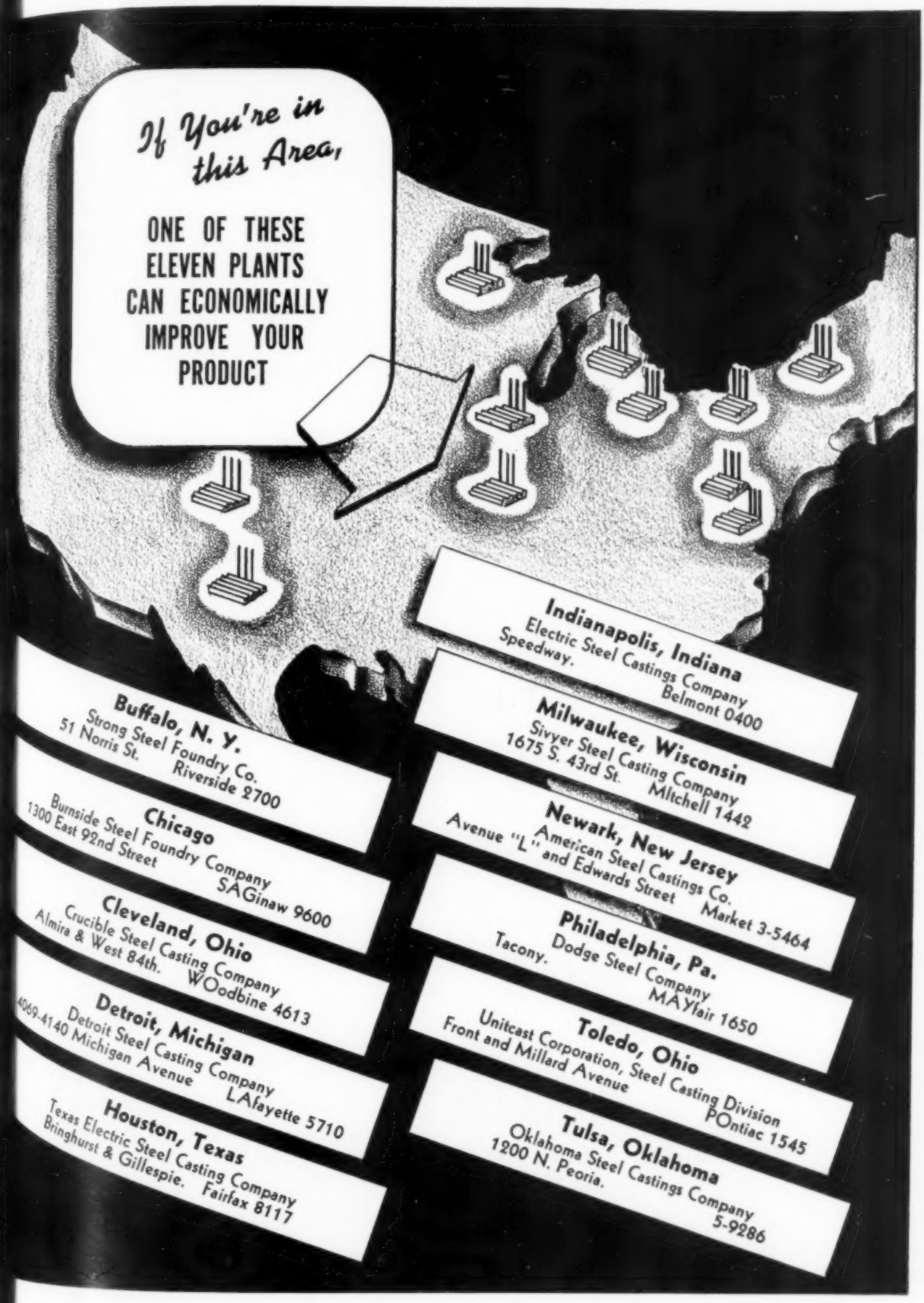
Consult with Ampco Engineers. Ask for data sheet "Aluminum Bronze as an Alternative Specification."

AMPCO GRADE		TENSILE STRENGTH	YIELD STRENGTH	ELONGATION IN 2"	RED. OF AREA	BRINELL HARDNESS
"	12	65-75,000	25-29,000	22-27%	22-27%	109-124
"	16	70-80,000	32-37,000	18-22%	16-20%	131-156
"	18	77-85,000	34-40,000	10-14%	6-10%	159-183
"	18-22	90-100,000	45-55,000	3- 7%	3- 7%	202-235
"	18-23	95-105,000	43-50,000	10-15%	12-18%	183-207
"	20	83-90,000	38-43,000	2- 6%	1- 4%	212-248
"	21	70-80,000	42,000 min.	1- 4%	0- 4%	285-311
"	22	70-85,000	45,000 min.	0- 2%	0- 2%	321-352

AMPCO METAL, INC.

DEPARTMENT MP-9 MILWAUKEE, WISCONSIN

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Texas Electric Steel Casting Company
Bringhurst & Gillespie. Fairfax 8117
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Electric Steel Castings Company
Speedway. Belmont 0400
Milwaukee, Wisconsin
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Avenue "L" and Edwards Street Market 3-5464
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Front and Millard Avenue POntiac 1545
Tulsa, Oklahoma
Oklahoma Steel Castings Company
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Heavy Forgings of Copper Steel

By M. L. Faure and M. Friart
Haumont Forge, Societe des Forges de la Providence

METALLURGISTS are well acquainted with the fact that the solubility of copper in ferrite is limited, and that steels containing 0.5 to 1.5% copper may be hardened by the precipitation of excess copper during cooling. Such conditions would be ideal for heavy forgings, but unfortunately some trials in 12-in. size with a steel containing 0.12% carbon, 0.85% copper showed marked brittleness after such hardening treatment. For this reason more complex steels were investigated. The addition of chromium in amounts of 0.35% or more improves the impact strength even more than it increases the tensile strength. A steel containing 0.18% C, 0.87% Cu, and 0.42% Cr, has well balanced fatigue strength, toughness and tensile properties in forgings 12 in. in diameter. The addition of a little nickel gives the same result and is also justified from the standpoint of forgeability. Raising the carbon content does not improve matters — rather the opposite, and the practical composition limits are 0.30% C, 1.0% Cu, 0.5% Cr.

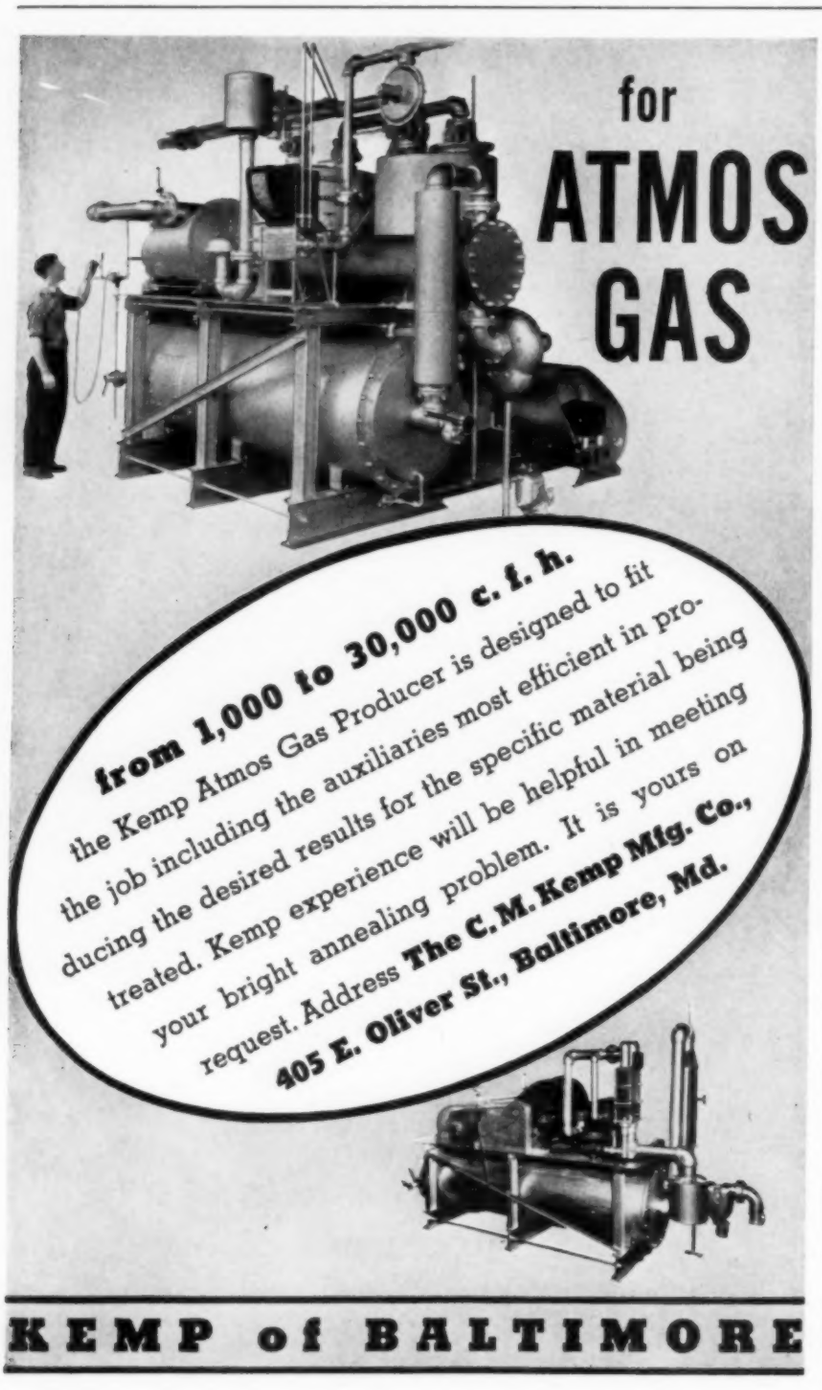
Heating practice before forging is important. In the above mentioned steels a rapid increase in ductility occurs when tested at about 1200° F., a temperature associated with maximum rate of change in the copper constituent. After teeming the ingot, therefore, it is desirable to interrupt the cooling at a temperature no lower than 1200° F. and place the ingot in a furnace for reheating, or if the ingots cannot be worked immediately they should be held in a soaking pit for several hours at 1200° F. and then slowly cooled in the pit.

Reheating should be gradual up to 1200° F., preferably starting with a cold furnace or a very low temperature. Cold ingots weighing more than 25 tons should be warmed slowly by any convenient means until they are thoroughly heated to about 200° F. It is best to use preheating furnaces even on blooms.

Hot Working these chromium-copper steels may require either more powerful hammers or presses for an equal amount of deformation, or utilize a larger number of reheatings so hotter, more plastic metal can be worked under lighter pressure. High finishing temperature is achieved by a final rapid forging.

Hot working of ingots should

(Continued on page 458)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Heavy Forgings

(Continued from page 458)

always be started with low pressures before performing any extensive deformation. The normal forging range is about 2200 down to 1750° F. for the copper-chromium steels and 2200 down to 1550° F. for the copper-nickel steels.

Surface Cracking is a well known phenomenon with copper steels, and it should also be equally well known that it is caused by the accumulation of copper out of the scaled surface, and its penetration into the sound underlying metal. This is counteracted by a modicum of nickel, usually obtainable from scrap alloy steel added to the openhearth charge. Knowing the cause of the cracks, the laboratory finding is understandable that no cracks appear even in high copper steels heated in a hydrogen atmosphere.

In practice no definite method of heating can be determined which will suppress cracks in copper steels, free of nickel. To *diminish* the tendency, the atmosphere and temperature of the furnace should be controlled and the flame should not be allowed to play upon the metal. The presence of cracks entirely on the surface and bearing no relation to the body of the metal means that a sufficient allowance for rough machining must be provided.

Heat Treatment is only partially related to the carbide critical points. Nevertheless the temperatures of two representative steels are as follows:

Composition	Cu-Cr	Cu-Ni
Carbon	0.28	0.22
Copper	1.00	0.94
Chromium	0.52	—
Nickel	—	0.40
Ac_1 (beginning)	1380	1335
Ac_3 (end)	1515	1545
Ar_3 (beginning)	1380	1380
Ar_1 (end)	1200	1140

For heavy forgings the hardening treatment consists of a preliminary treatment—reheat-

ing and quenching either in air or in a liquid — and a final tempering. We will not discuss here the liquid quench.

Preliminary Treatment — Normalizing by heating to $Ac_3+50°$ before hardening results in a more uniform structure in the as-forged steel, suppresses forging strains, makes for uniform supersaturation of the copper in the ferrite and throughout the part, and finally eliminates temper brittleness in a steel whose finish forging temperature is more than 1800° F., and which is to be hardened in the as-forged condition. We have found for the Cr-Cu and Ni-Cu steels that the temperature range for solution of copper is between 1250 and 1400° F. A temperature equivalent to $Ac+50°$ is satisfactory for all purposes.

The cooling speed after reheating should be rapid enough that the copper does not separate from solid solution. In the region of 1100° F. it should be a maximum of 200° per hour to obtain the highest degree of hardening. More rapid chilling is undesirable; in large forgings a quench in warm or boiling water may be necessary to achieve the desired speed.

Final Treatment — The eventual hardness depends on the chemical composition of the steel, the temperature and time of re-heating, the degree of purity, and the speed of cooling after re-heating. Studies of hardness versus aging (reheating) temperature show the characteristics of typical precipitation hardening. For example, the steels indicated above develop a maximum hardness and strength after heating about 4 hr. at 925° F.; however impact strength has suffered. To improve the latter a heating up to 24 hr. may be necessary; this causes a loss of tensile strength (due to "over-aging") but is warranted if a high impact value is more to be desired in the finished forging.

2½ Tons of Chromium-Nickel Alloy Saved by Rebuilding Furnace

By Earl A. Lerner, Assistant Manager Alloy Dept.
American Manganese Steel Division

Making the most of what we have is an excellent way to help win the war. Scarce metals can be made to go farther if all plant engineers will make conservation of them one of their first thoughts.

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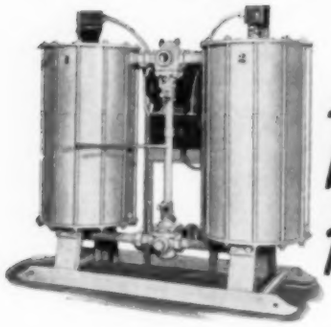

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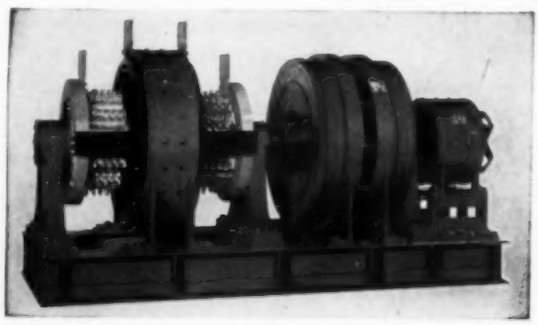

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